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THE FRANKLIN INSTITUTE.

The First Atlantic Telegraph Cable.

(A Supplementary Note.)

BY JOHN MULLALY.

The illustration of the Atlantic Telegraph Squadron shown in accompanying picture, which was composed of the four war-ships employed in the laying of the great ocean cable, is a minute reproduction of a large lithographic print published under the patronage of the Commanders and officers of the vessels and was dedicated by the artist to Hon. George M. Dallas, at that time (1857) United States Envoy Extraordinary and Minister Plenipotentiary to Great Britain.

The Squadron consisted of the U. S. Steam Frigate Niagara and the British line-of-battle Ship Agamemnon, both vessels having been selected not only as the largest men-of-war in the respective navies of the two nations, but because they were also

the best adapted otherwise for the important undertaking in which they were to be engaged. They were accompanied by two smaller vessels, the U. S. Frigate Susquehanna, acting as the escort of the Niagara, and the British Frigate Leopard, doing similar duty for the Agamemnon.

The Niagara, as shown in the engraving, had a capacity of at least three thousand five hundred tons, and the Agamemnon had about equal register. The two ships were built on entirely different models, the first having been designed on the plan and lines of the clipper ship, and the second on the old style of the ninety-six gun ship of the line. In point of speed there was no comparison, the American vessel being much the faster of the two, a fact, however, which did not detract from the usefulness of the Agamemnon in the work of cable laying, which rarely exceeded a speed of seven or eight miles an hour.

In the preparation of the ships for the work to which they were assigned it was found necessary not only to strengthen the decks on which the Cable was to be coiled, but to make radical changes for its proper distribution. Large circles, fenced around with heavy planks to the height of four or five feet and shored up with massive beams, formed the receptacle in which the Cable was laid in successive layers around a central cone. Thus the Cable on the Niagara was, with a due regard to the "trimming" of the ship, divided into seven parts, or sections, three of which were placed on the main deck, two on the second deck and the balance in the hold.

The armament of the ship had been removed and every available foot of space that was required for the machinery and appliances in the submersion of the great submarine line was appropriated and even the sleeping quarters of the officers in the Ward Room were invaded. The whole internal aspect of the Niagara, in all its decks, was changed. The huge warship, (huge for that day) which had been armed at every point with great guns and other weapons of destruction, was transformed into an agent of peace and industry and science for the binding together of nations in commercial intercourse and friendly relations. The ponderous cannon had been unshipped and relegated to the forts and arsenals on land, and the magazines were emptied of their tons of explosives and deadly missiles, while the paying-out machinery, over which the Cable was carried into the depths of the ocean,

two-and-a-half miles beneath the surface, occupied more than three-fourths of the main deck. At the stern of the Niagara was erected the grooved wheel over which the Cable passed in its descent to its resting place on the Telegraph Plateau, which extended at a uniform depth between Ireland and Newfoundland, the two termini, or points of connection of the Atlantic Telegraph.

While it is true that the two warships which had been selected on account of their carrying capacity were otherwise unfitted for the work of cable laying, it is very doubtful if, in view of the magnitude of the enterprise and the amount of capital required, it would have been accomplished but for the international co-operation extended by the two governments and the timely, effective and substantial aid thus afforded. Had the undertaking depended solely on its merits as a commercial project its accomplishment in the face of the incredulity, and even suspicion in some quarters with which it was regarded, it would most probably have been postponed for another generation.

In view of all the circumstances attending the early history of the Atlantic Telegraph, the failures and losses and disappointments by which the first trials were beset, though finally crowned with a success that proved its practicability, the illustration of the united ships of the two nations engaged in the solution of one of the greatest of scientific problems possesses more than ordinary historical interest.

TASMANIA, like Utah, has its smelter-smoke question, a deputation of members of the town board of Queenstown having recently taken up the question of preventing or minimizing the escape of sulphurous gases from the Mt. Lyell furnaces. Mr. Sticht held out very little hope of an amelioration of the difficulty. This is one of the great metallurgical problems of the day, being of far more consequence now than formerly, because of the immensely greater volumes of gas that are discharged by modern smelting works, which have been greatly increased in size. The problem is engaging the attention of the ablest metallurgists in several parts of the world.—*Eng. and Min. Journal.*

ACCORDING to the Queensland *Government Mining Journal* a discovery of tin is reported from Waratah, Tasmania. The lode is said to be twelve feet wide and thirty per cent. ore has been taken out.

BOILER CONSTRUCTION AND RATING.

Students and philosophers frequently speak of cycles in connection with subjects under their attention. Cycles occur in trade as in other realms. It is only a few years since the manufacturers of house heating boilers departed from the egg shell or beehive type of construction to those which presented in the combustion chamber additional surface for the absorption of the heat radiated from the fire, and also impinged upon it by the flames and the products of combustion. It is not so far back when house heating boilers were made of two dome shaped castings of different dimensions, so that when one was set over the other there existed a space between them through which water could be heated and circulated or steam generated. The bottom connection of these two castings was sometimes made tight all around the outer circumference by means of a rust joint. Boilers of this construction, while efficient in heating large quantities of water, as in greenhouse heating, lacked important qualifications for economy when used for heating residences, and the evolution in boiler production resulted in constructions which presented additional surface exposed to the fire and gases, and which provided for a sufficient travel of the products of combustion before their liberation to the chimney to absorb as much of the heat they carried as practicable.

This led to designs which were radically different from the original egg shell boiler, with its direct draft and arrangement, presenting only that surface exposed by the under side of the egg shell. This departure had the effect of causing the introduction into the egg shell construction of surfaces arranged in the form of baffle plates to secure the longer fire travel and secure some economy. In the main the trend has been away from the old bee hive construction, but at various times some manufacturer has taken the downward and backward step, though the latest productions have proved more efficient and more economical and more satisfactory to the final buyer than those which rendered service to the final buyer only at the expense of extravagant consumption in fuel and frequent firing.

The evolution of the boiler from the egg shell type to the best type of horizontal sectional boilers having a long fire travel and staggered flues, and to the vertical sectional boilers of the return flue type, has progressed steadily until the better types are quite generally made and used. These steps have been attended, however, with many divergings. Frequently those who were better salesmen than engineers have been able to sell their productions of the old inferior types on the claims of equal capacity and lower price. This has led to some annoyance to those buyers of boilers who were not thoroughly capable of determining capacities. Notwithstanding the ratings given by manufacturers to their constructions, competent engineers frequently depend upon their own calculations regarding the power possessed by the grate surface, the fire surface and the flue surface exposed.—*The Metal Worker.*

Mechanical and Engineering Section.

(Stated Meeting held Thursday, March 7th, 1907.)

The Modern Locomotive.

Mr. Paul T. Warner.

It can truly be said that the steam locomotive has reached a crucial point in its development. He would be a bold prophet who would venture to say that the limit of capacity has been reached. If, however, future locomotives are to be made more powerful than the largest now building, it is probable that some radical changes in design must be made in order that such an end may be accomplished. With the enormous amount of freight traffic handled at the present day, there is a constant demand for locomotives of increased tractive power, in order that the tonnage may be removed with a fair degree of economy. The requirements of modern passenger service necessitate the hauling of express trains which are frequently as heavy as were the freight trains of a few years ago. This fact, coupled with the higher speeds of to-day, has necessitated the construction of locomotives having exceptional steaming capacity; and the demands made upon the engines employed in this class of service are daily becoming more exacting. The electric locomotive is now entering the field, and with its increased possibility for higher capacity, is receiving great attention from all who are interested in the motive power problem. The day of the steam locomotive has not yet come to an end, but the law of the survival of the fittest must eventually decide the question; and in certain localities where special conditions exist, the electric locomotive has already demonstrated its superiority. This fact, however, is only assisting in the further development of the steam locomotive; and the problem of how its efficiency may be improved, is receiving the

closest attention of motive power officials and locomotive builders.

Concentration of power is essential in order to meet conditions as they exist in the mechanical world to-day; and the modern locomotive is a striking illustration of the fact. The locomotives exhibited at the St. Louis Exposition of 1904 showed an average increase in weight over those shown at Chicago in 1893, amounting to more than 50 per cent. So rapid has been the growth in size and tractive power, that the locomotive has set the pace for improvement in practically all other branches of railway service. Its introduction has compelled the use of stronger bridges, heavier track construction and improved shop and roundhouse facilities. The great weight of modern freight trains, made possible by the high tractive power of the locomotives employed, practically necessitates the use of freight rolling stock equipped with steel underframes, improved draft gear, and automatic couplers and air brakes. On many roads the largest locomotives are still in advance of the facilities provided for maintaining and repairing them. In handling freight traffic, difficulties are frequently experienced because of the continued use of old cars having draft gear inadequate to stand the shocks and stresses to which it is subjected. The successful firing of the largest engines presents another problem, as it is almost beyond the ability of the fireman to handle the fuel required. The automatic stoker promises relief in this direction, and its more general use may be expected with the further growth of the locomotive.

As engines have increased in size, the number of types in use has been multiplied. Formerly the well known eight-wheel, or American type of locomotive, handled practically all the passenger and a large proportion of the freight traffic of the country. It now, however, has become inadequate, and new types have been developed to meet the changed conditions. In fast passenger service, for example, the ability of the locomotive to meet requirements depends largely upon the maximum horsepower which can be developed. The boiler then becomes the limiting factor, and its capacity must be large in proportion to the tractive power of the engine. Opposed to this class of work is heavy freight service, requiring a locomotive having great tractive power and consequently ample weight on the driving

wheels. As this tractive power is developed at slow speeds, the boiler power is not proportionately as great as in the fast passenger locomotive. Between these two extremes may be placed fast freight and heavy medium speed passenger service. This work necessitates locomotives having ample weight on the driving wheels and high steaming capacity, and types of engines, which are satisfactorily meeting these conditions, have been developed. In addition there are designs for switching and local service, heavy mountain pusher service, and other special work.

From what has been said it is evident that a consideration of the "Modern Locomotive" must deal with those peculiar features which have made possible the meeting of present day demands. The source of power, in the steam locomotive, is its boiler; and therefore the first requisite in a high powered engine, is ample steaming capacity. This necessitates a grate of sufficient size to burn the required fuel at an economical rate; a fire box of ample volume and approved form, and sufficient heating surface to transmit the heat of combustion to the water, without undue waste at the stack. Provision for good circulation is also a necessity; as well as an arrangement in the front end, or smoke box, that will equalize the draft through the tubes, and result in the most efficient draft action on the fire.

Bituminous coal-burning locomotives of ten or fifteen years ago, such as were exhibited at the Columbian Exposition of 1893, were almost invariably constructed with fairly deep fire boxes having the grate placed between the driving wheels. The width of the fire box was thus strictly limited. As locomotives increased in size, the grate was lengthened, until successful firing became difficult, and in the largest engines, almost impossible. The time was clearly at hand when increased grate area and boiler power were essential; and it became evident that a radical change of design, especially in the case of fast passenger locomotives, was necessary in order to secure the end desired.

In 1895 the Baldwin Locomotive Works built for the Atlantic Coast Line, an engine which was the forerunner of the type now largely used in high speed service. This locomotive had a four-wheeled leading truck and two pairs of driving wheels, which were placed as far forward as possible. The pistons were connected to the second pair. The fire box was placed behind the rear driving axle, thus permitting it to be made of ample depth

and volume. To carry the resulting overhang, a pair of trailing wheels was introduced. This locomotive, to which the name "Atlantic" type was given, was built to fulfill a difficult guarantee, and proved successful. A large number of similar engines followed, and the type was soon adopted by other builders in this country and abroad.

The next step in the development of the "Atlantic" type locomotive was to provide a wide fire box for burning bituminous coal. The grate was placed entirely behind the driving wheels, its width thus being limited only by the loading gauge, while ample depth of furnace was readily secured. Thus there was developed the type of locomotive which to-day is working a large portion of the fastest traffic, not only in this country, but also in Great Britain and on the Continent of Europe.

The addition of the trailing wheel is essential in locomotives having large driving wheels combined with deep wide fire boxes, and a number of types possessing these features have been developed during the past six years. The accompanying diagram shows these classes in outline, as compared with corresponding types which preceded them. The diagrams show clearly how the wheel arrangements have been modified to suit the boiler requirements. The changes noticed have resulted in providing the locomotive with increased boiler capacity in proportion to the weight carried by the driving wheels—in other words, to the tractive power. Thus the eight wheeled engine, formerly so generally used in high speed service, carries about 66% of its total weight on the driving wheels; while in the modern "Atlantic" type, the proportion is about 55%. Assuming, therefore, that an eight-wheel and an "Atlantic" type engine carry the same weight on their driving wheels, the total weight of the "Atlantic" type will be about 20% in excess of the eight-wheeler. This additional weight is utilized principally in providing a larger boiler. Hence while the tractive powers of the two engines at slow speeds will be the same, the maximum horse-power which can be developed in the "Atlantic" type will be in excess of that of the eight-wheel engine. It is for this reason that in such severe service as that between Camden and Atlantic City, for example, "Atlantic" type engines are able to maintain the schedules required where the eight-wheel engines have proved inadequate.

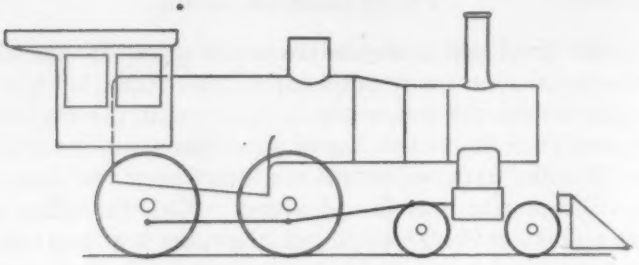
The "Pacific" type locomotive stands next in the series, and

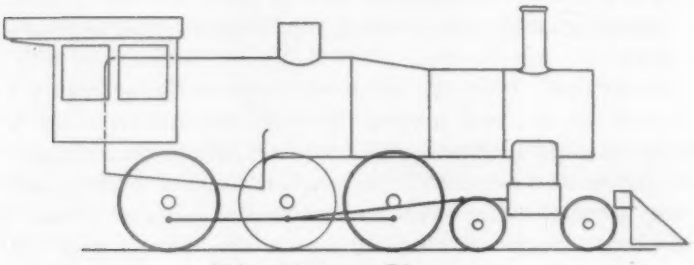
has been developed from the ten-wheel type. It has the same characteristics, in many respects, as the "Atlantic" type, and is suitable where the trains are so heavy that the tractive power required necessitates the use of three pairs of driving wheels. The "Pacific" type represents the most powerful class of passenger locomotive thus far produced. With the wheel arrangement and boiler design employed, the tubes are long—frequently twenty or twenty-one feet. Ample heating surface is thus provided, and the fire box can be made of most liberal dimensions. Where a passenger locomotive having great tractive power and high steaming capacity is desired, the "Pacific" type is frequently selected.

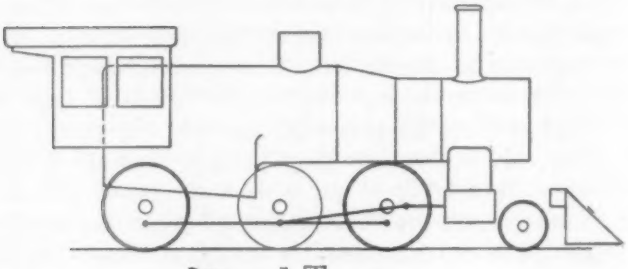
The "Prairie" type, which stands next in the series, is a development of the well known "Mogul" locomotive, and is admirably adapted to fast freight service, where an exceptionally powerful boiler is wanted in combination with three pairs of driving wheels. The tubes are somewhat shorter than in a Pacific type engine having the same size wheels and driving wheel base. The front end of the engine is supported by the fulcrum of an equalizing beam placed under the cylinder saddle, and this arrangement is liable to result in rather unsteady riding at high speeds; hence for fast service, the "Pacific" type is usually regarded as preferable where a six-coupled engine is required. On some roads, however, the "Prairie" type is successfully employed in fast passenger service. Engines of this type were first used in 1900 by the Chicago, Burlington and Quincy Railway in the Middle West, whence the name was derived.

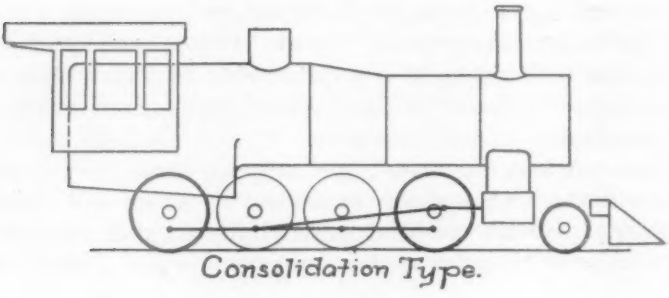
For many years the "Consolidation" type has been (and still is) regarded as the most suitable for heavy freight service. With the moderate size driving wheels usually employed, a wide fire box can be placed over them without difficulty. If, however, an exceptional depth of furnace is needed, as is desirable for burning lignite, for example, the "Mikado" type is used to advantage. This class took its name from a number of locomotives which were shipped to Japan by the Baldwin Locomotive Works about ten years ago.

There are also one or two special types which have come into service during recent years, examples of which will shortly be presented. It must not be supposed, however, that the American ten-wheel and Mogul types have become obsolete. They are still

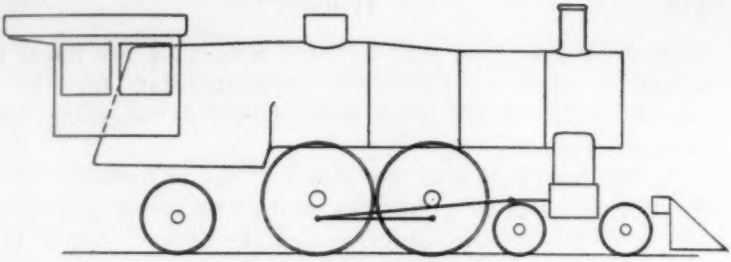




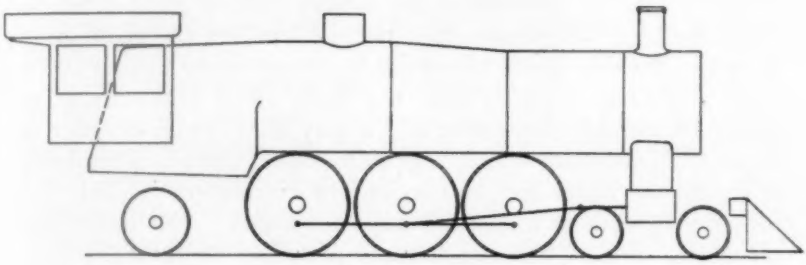




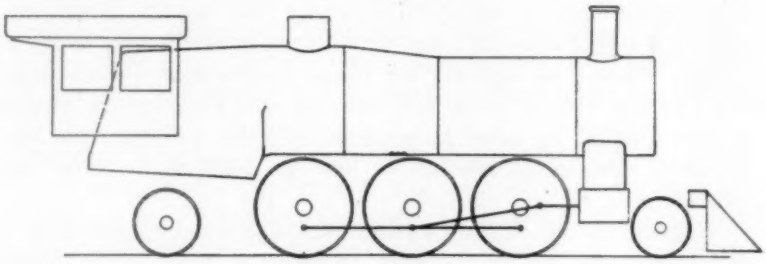
Types of the American Locomotive



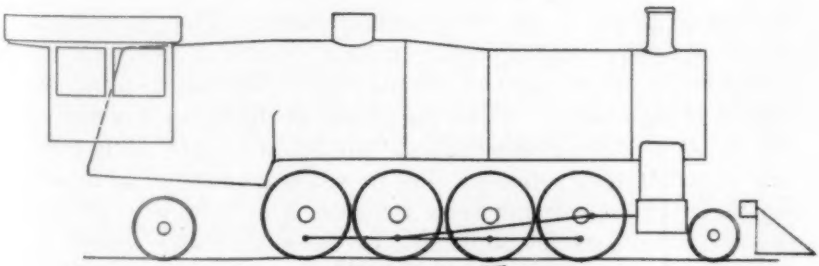
Atlantic Type.



Pacific Type.



Prairie Type.



Mikado Type.

Types of the American Locomotive

extensively used, and may be fitted with wide fire boxes if the wheel diameters are sufficiently moderate; but for the most severe service, where great boiler power is necessary, trailing wheels are usually required.

As has been indicated, the wide fire box was adopted in order to provide sufficient grate area, and at the same time keep the length of the furnace within reasonable limits. Ample heating surface can be secured in a boiler having a narrow fire box, but the ratio of grate area to heating surface is then so high that an excessive rate of combustion per square foot of grate must be maintained. Furthermore, in a narrow fire box boiler of large diameter, the side sheets of the fire box must curve outward at a sharp angle in order to meet the shell. It is thus difficult to secure a favorable disposition of the stay bolts, while in order to obtain the maximum width of grate possible, there is a tendency to cramp the water legs and so impede circulation. With the wide fire box, these difficulties can be avoided. The water legs are nearly vertical, and can be made of ample width without restricting the grate area.

The effort to secure improved circulation is noticeable in recent boiler designs, as is evidenced by the use of wider water spaces and more liberal tube spacing. It is found that better service is secured by spacing the tubes farther apart, even though the heating surface is thereby reduced; and the practice of filling a boiler as full of tubes as possible, in order to secure the maximum number of square feet of heating surface, is now being abandoned.

Regarding the driving mechanism, the most conspicuous development, during recent years, is found in the balanced engine. In the ordinary two cylinder locomotive, excess weights are placed in the driving wheel counterbalances, to neutralize the disturbing effects of the reciprocating parts. The centrifugal effects of these weights, when running, results in a periodic increase of the wheel pressure on the rail, which may become excessive at high speeds. With the advent of the heavy locomotive the problem of the counterbalance has become particularly difficult of satisfactory solution. The most logical method of avoiding the so-called hammer blow is to use four cylinders, placing the two cranks on the same side of the engine 180° apart, so that the reciprocating weights oppose one another in movement,

and their disturbing effects are thus neutralized. Compound cylinders can be readily applied to a locomotive of this type, and the economic advantages due to double expansion of the steam can thus be realized.

Balanced compound locomotives have been used abroad for some years, especially in France, where they are employed on practically all the high speed trains. European designs have generally been regarded as too complicated for successful use in this country, but in 1902 the Baldwin Locomotive Works introduced a simplified form of balanced compound locomotive which is adapted to American conditions, and has given good results in service.

In the Baldwin engine, the cylinders are placed in line across the locomotive, the high pressure being between the frames, and the low pressure outside. A single piston valve controls the steam distribution to each pair of cylinders, which, with their common steam chest, are cast in one piece with half the saddle. Wherever possible, the leading pair of driving wheels is moved back sufficiently to enable it to be driven by the inside (high pressure) cylinders, and is then provided with a cranked axle. The outside cylinders are coupled to either the first or second pair of driving wheels, as preferred. When the latter arrangement is adopted, the outside guides and piston rods are lengthened, in order to keep the length of the outside main rods within reasonable limits.

The crank axle has frequently been regarded as a weak point in an engine of this type, but with the materials and methods of manufacture now available this member has been so perfected that little or no trouble is experienced in service. The latest form of axle used by the Baldwin Locomotive Works is built up and composed of seven pieces, which are pressed together in a hydraulic machine. The central member is of cast steel. This form of axle, while heavier than the solid forged type, is less expensive to make, and the forged parts can be thoroughly worked and specially adapted to the service they have to perform. Should any part require renewal, it can be replaced without discarding the entire axle.

Owing to the fact that, in this type of locomotive, the piston thrusts on the same side of the engine oppose one another, the frame stresses are greatly reduced. It is found in service that

these engines are practically immuned from frame breakage. This is an important point, as it does away with an annoying feature which not infrequently exists in large two-cylinder locomotives.

The balanced compound locomotive, when properly handled and maintained, has proved highly efficient and economical in service. In July, 1904, the Chicago, Burlington and Quincy Railroad carried out a series of tests with engine No. 2700, a balanced compound Atlantic type locomotive, and three single expansion engines. The tests were run in fast passenger service, over a difficult section of the road, in which the total rise is 2044 feet in a distance of 142.9 miles. The compound developed an average indicated horse-power hour on 24.37 pounds of water, as against 30.10 pounds for the most economical single expansion engine tested. That is, given two locomotives, one a compound and the other a single expansion, both having the same sized boiler, the compound can develop 20% more horse-power than the other. Locomotive No. 2700 proved its ability to make good this claim, and on one occasion made time with a train of twelve cars, weighing with the engine and tender 719 tons. None of the single expansion locomotives was able to equal this performance. Subsequent tests carried out on this road have substantiated these results.

The American Locomotive Company has also produced a balanced compound locomotive, to the designs of Mr. F. J. Cole. In this engine the high pressure cylinders, which are located between the frames, are placed in advance of the low pressure, which are outside the frames. The high pressure pistons are connected to the leading axle, which is cranked, while the low pressure are connected outside, to the second pair of driving wheels. With this arrangement, connecting rods of approximately equal length and weight are secured. This system of compounding has been applied to a number of locomotives of both the Atlantic and Pacific types.

The introduction, during the past two years, of the Walschaerts valve gear on a large number of American locomotives, is a matter which deserves notice. For many years the use of the Stephenson link motion on locomotives was, in this country, practically universal. As long as engines were of moderate size, it gave satisfaction; but with the introduction of the modern

heavy locomotive, certain difficulties were encountered. Axles have grown to such a size, that the diameter of the eccentrics must be considerable in order to get the required throw. This increases the velocity of the rubbing surfaces, tending to result in heating. The parts of the gear become heavy and cumbersome, and their inaccessible location renders proper inspection and lubrication difficult. In order to overcome these disadvantages, a number of roads have recently introduced the Walschaerts motion. This gear, which is of the radial type, and named after its inventor, was patented in Belgium in 1844, and is extensively used on the Continent of Europe. It is placed entirely outside the driving wheels, and all parts are readily accessible. The principal motion is derived from a return crank, secured to one of the crank pins. This crank actuates a link, which is trunnioned at its middle point. The movement of the link is transmitted to the valve through a radius rod, which is provided with a sliding link block; and by shifting the block from one end of the link to the other, the motion of the engine will be reversed. The return crank is set without angular advance; and, to give the valve the desired lead, a combination lever, driven from the crosshead, and connected to both the radius rod and valve stem, is employed. This lever is so proportioned that, if the radius rod be held stationary, the valve will move a distance equal to twice the lap plus the lead, during each stroke of the crosshead.

As far as the steam distribution is concerned, the Walschaerts gear differs from the Stephenson chiefly in that it gives a constant lead, while with the Stephenson gear the lead increases as the cut off is shortened. The latter arrangement is ordinarily regarded as desirable in a locomotive, but in actual service the two gears seem to give practically the same results, and when properly designed and in good condition, neither gear shows a decided superiority over the other. The introduction of the Walschaerts gear has been due entirely to mechanical reasons, and on those lines where it is now in use, it is generally looked upon with favor.

Both the balanced slide and the piston valve are extensively used on single expansion locomotives carrying high steam pressures. The piston valve is usually made hollow, and arranged for inside admission. The pressure on the two ends of the valve

is thus equalized, and as only low pressure steam is present in the ends of the steam chest, the valve stem stuffing box can readily be kept tight. The Walschaerts gear is advantageously used with this form of valve, as it is then impossible, owing to the constant lead, for the cylinder to be sealed when the piston is at the end of its stroke. This is an important feature, as the piston valve cannot lift from its seat in order to relieve compression. It is also possible, with this form of valve, to locate the centre line of the steam chest outside of the cylinder centre line, and thus place all the members of the valve gear in the same vertical plane, which is desirable. The most recent Consolidation and Atlantic type locomotives on the Pennsylvania Railroad may be cited as interesting examples of the use of piston valves in combination with the Walschaerts valve gear.

Before describing any specific examples of modern locomotives, brief reference should be made to the use of superheated steam. Extensive experiments along this line have been carried out in Germany, and also on the Canadian Pacific Railway, while a few other lines in this country have been trying various forms of superheaters. In the arrangement usually used on the Canadian Pacific, a certain number of boiler tubes are replaced by tubes of considerably larger diameter. These large tubes contain the superheater pipes, through which the steam circulates on its way to the cylinders. This device superheats the steam effectively; although with certain kinds of coal, the tubes are liable to become choked. The fire tube type of superheater has been developed, in this country, by the American Locomotive Company, and has been recently modified by the Canadian Pacific Railway, which has a large number of locomotives equipped with it.

The Baldwin Locomotive Works are at present developing a smoke box superheater. This device consists of upper and lower drums, which are connected by rows of tubes, among which the hot gases circulate while passing through the smoke box. The live steam is passed through successive groups of tubes, thus utilizing as fully as possible, the heat stored in the waste gases. The first superheater of this type was applied to a large freight locomotive built for the Atchison, Topeka and Santa Fe Railroad about two years ago. It has given good results and a number of other locomotives are now being equipped with the device.

The use of superheated steam is attended with unquestioned

economy, and if it is found that superheaters can be maintained without undue expense, their more general use may be expected in the future.

Having now considered some of the features of the modern locomotive, a few specific examples of engines built by the Baldwin Locomotive Works will be illustrated and briefly described.

The accompanying cut represents an Atlantic type locomotive, built in 1904 for the Chicago and Alton Railway. This engine was constructed to designs adopted as standard by the Associated Lines, and was exhibited at the St. Louis Exposition. The cylinders are single expansion, 20 inches in diameter

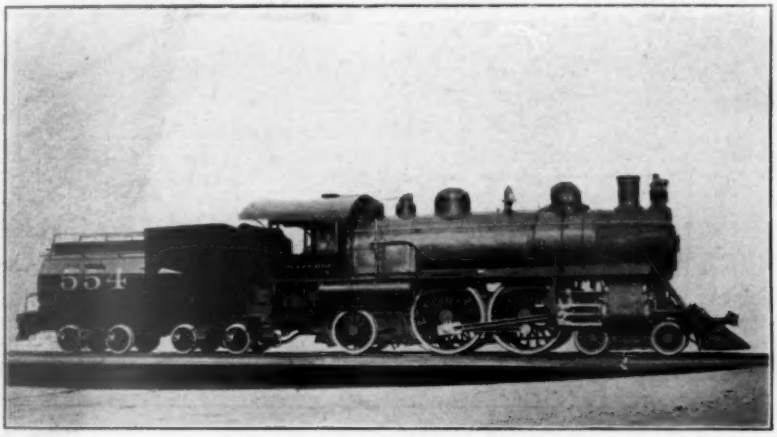


Fig. 1. Atlantic Type Locomotive. Chicago and Alton Railway

by 28 inches stroke. They are fitted with piston valves, which are actuated by Stephenson valve gear. The driving wheels are 81 inches in diameter. The boiler has a wide fire box and carries a steam pressure of 200 pounds per square inch. The tender is of the Vanderbilt type, with cylindrical water tank.

A Pacific type locomotive, similar in many respects to the engine just presented, is shown on the next cut. It was built for the Union Pacific Railroad, and is one of a large number of similar locomotives now in heavy passenger service on the Associated Lines. The cylinders are 22 inches in diameter, as against 20 inches in the Atlantic type engine; while the diameter of the driving wheels is 77 inches. To keep the rigid wheel base within

reasonable limits, the Rushton radial trailing truck is used on this engine, instead of the rigid trailing wheels employed on the Atlantic type. The rear frames are separate from the main frames, the splice being located back of the rear pair of driving

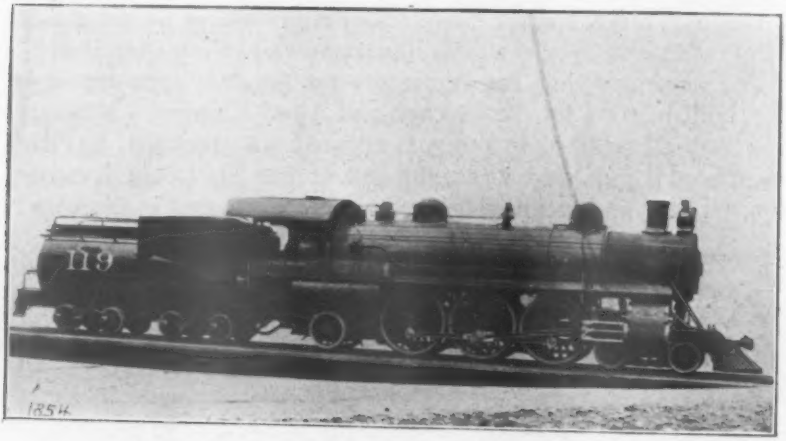


Fig. 2. Pacific Type Locomotive. Union Pacific Railroad

wheels. This is an excellent example of a six-coupled locomotive for heavy passenger service.

The Mogul locomotive shown on the next cut is one of a number used on the Missouri, Kansas and Texas Railway. This

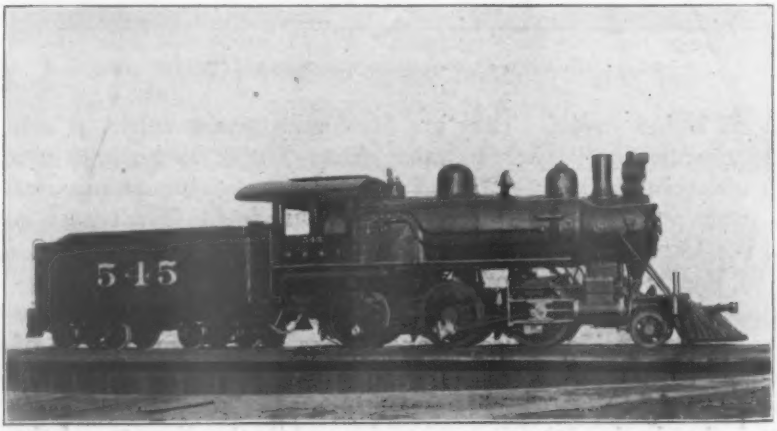


Fig. 3. Mogul Type Locomotive. Missouri, Kansas and Texas Railway

engine represents a type which is admirably adapted to freight service where moderate steaming capacity and tractive power will suffice. The cylinders are 20 inches in diameter by 28 inches stroke. Balanced slide valves, actuated by the Stephenson link motion, are employed. The driving wheels are 63 inches in diameter. The boiler has a wide fire box placed above the rear pair of driving wheels, and carries a steam pressure of 200 pounds per square inch.

The ten wheel locomotive next shown was built in 1905 for the Chicago, Rock Island and Pacific Railway. This type is suitable for heavy passenger or fast freight service. The cylinders are 22 inches in diameter by 26 inches stroke, and the driv-

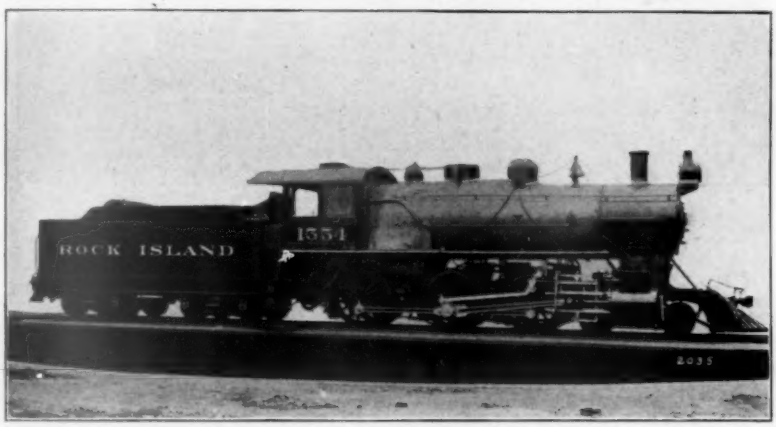


Fig. 4. Ten Wheel Locomotive. Chicago, Rock Island and Pacific Railway

ing wheels are 63 inches in diameter. The boiler has a wide fire box, and carries a steam pressure of 185 pounds per square inch. The engine is equipped with balanced slide valves, actuated by Walschaerts gear.

A Consolidation locomotive for the same road is shown on the next cut. This type of engine is the most popular for heavy freight service. Nearly 90 per cent. of the total weight is available for adhesion; hence a relatively high tractive power can be secured, and as the weight is distributed over four pairs of wheels, excessive axle loads can be avoided. This locomotive is another illustration of the application of the Walschaerts valve motion. The cylinders are 23 inches in diameter by 30 inches

stroke. With 63 inch driving wheels, and a steam pressure of 185 pounds, the tractive power is 39,600 pounds. Eighty-three locomotives of this class were built by the Baldwin Locomotive Works in 1906 for the Rock Island system.

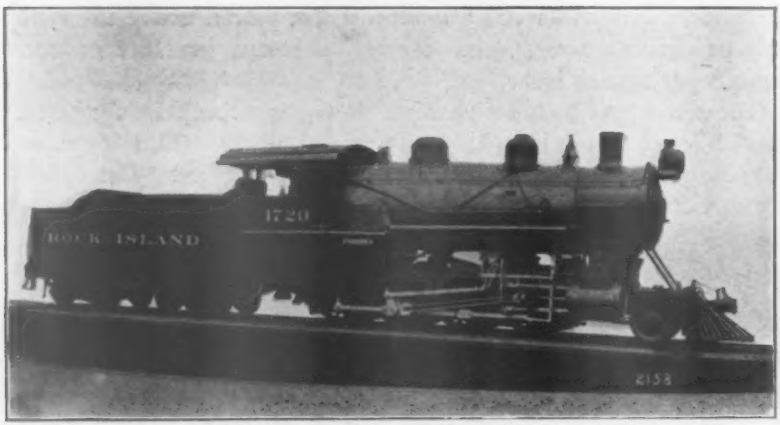


Fig. 5. Consolidated Type Locomotive. Chicago, Rock Island and Pacific Railway

The next cut represents a balanced compound Atlantic type locomotive for the Atchison, Topeka and Santa Fe Railway. Practically all the express traffic on this road between Chicago and La Junta, Colorado, is being worked by engines of this

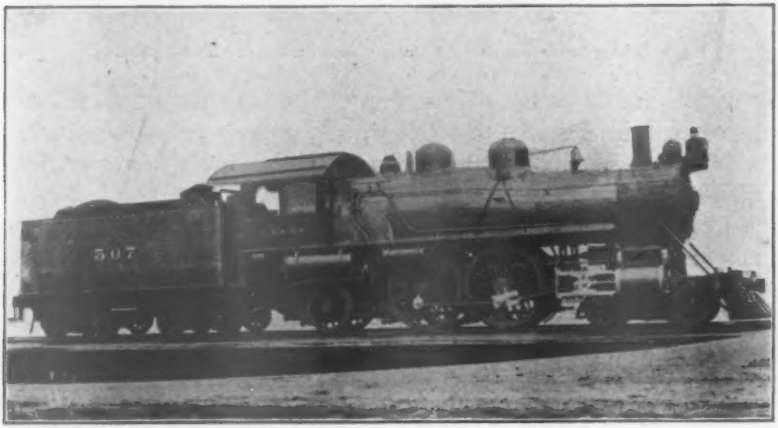


Fig. 6. Balanced Compound Atlantic Type Locomotive. Atchison Topeka and Santa Fe Railway

type, and they are giving excellent satisfaction. Reference has previously been made to the arrangement of the cylinders and running gear in this type of locomotive. In the engine now shown, all the pistons are connected to the leading pair of driving wheels. The cylinder dimensions are 15 and 25 inches diameter for the high and low pressure respectively, the common stroke being 26 inches. The driving wheels are 79 inches in diameter. The boiler carries a steam pressure of 220 pounds per square inch. This locomotive weighs, in working order, 193,700 pounds, of which 101,400 pounds are carried on the driving wheels.

A balanced compound locomotive for the Pennsylvania Lines

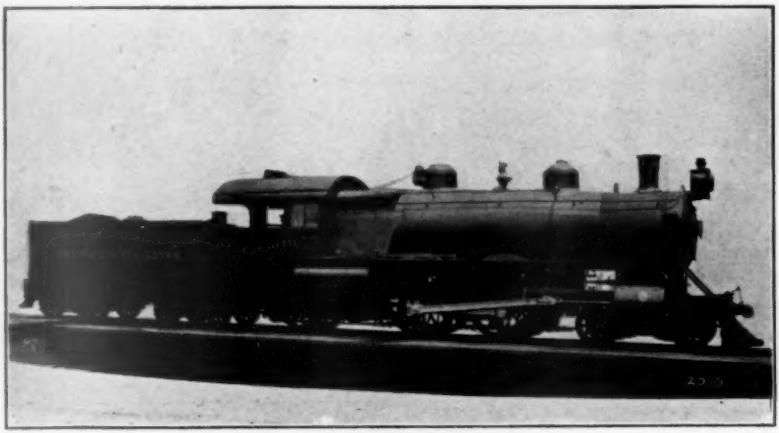


Fig. 7. Balanced Compound Atlantic Type Locomotive. Pennsylvania Lines West of Pittsburg

west of Pittsburg is next shown. In many of its details this engine follows Pennsylvania Railroad practice. The outside main rods are connected to the second pair of driving wheels—a plan which is frequently adopted, by the Baldwin Locomotive Works. for Atlantic type locomotives having this cylinder arrangement.

The accompanying cut represents one of fifty-seven balanced compound Prairie type locomotives now being delivered to the Atchison, Topeka and Santa Fe Railway. These engines are designed for fast freight service, and are the heaviest six coupled locomotives thus far constructed by the builders. The total weight is 248,200 pounds, of which the driving wheels carry

174,700 pounds. The tractive power, working compound, is 37,830 pounds.

The arrangement of the cylinders and allied parts presents some interesting features. Owing to lack of room it is impossible, in a locomotive of this pattern, to connect the pistons to the leading driving axle. The inside cylinders are therefore inclined at an angle of 7°, and all four pistons are connected to the second pair of driving wheels. The inside main rods pass above the leading driving axle. With this arrangement, the two cranks on the same side of the engine are placed 173° apart, so that the pistons may start their strokes at the same instant. A

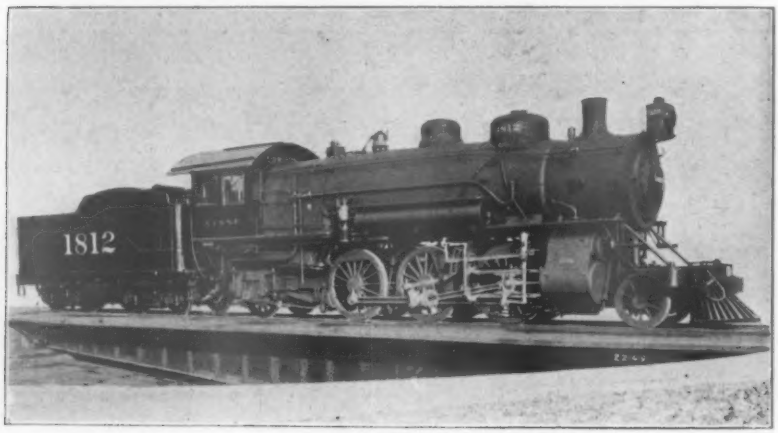


Fig. 8. Balanced Compound Prairie Type Locomotive. Atchison, Topeka and Santa Fe Railway

single piston valve, on each side, controls the steam distribution. The valves are driven by means of the Walschaerts motion.

The boiler is exceptionally large for an engine of this type, and carries a steam pressure of 225 pounds per square inch. The diameter is 76 inches at the front end and 82 inches at the steam dome. The fire box is wide, extending out over the trailing wheels. The total heating surface is 4017.8 square feet and the grate area 53.5 square feet.

The trailer truck is of the Rushton type, with outside journals. The weight carried by the truck is transferred to the boxes through swing links and the truck frame is secured to a radius bar, so that the wheels assume a radial position on a curve. This

reduces the rigid wheel base to the distance between the front and back driving wheels.

Another Santa Fe locomotive, designed for heavy freight service, is shown in the accompanying cut. This is one of over 150 locomotives of the Santa Fe type, which have been built for this road during the past four years. The engine is carried on five pairs of driving wheels and a two-wheeled radial truck at each end. The driving wheels are 57 inches in diameter. The cylinders are tandem compound, 19 and 32 inches in diameter by 32 inches stroke. Each high pressure cylinder is bolted to the front head of the corresponding low pressure cylinder, and both

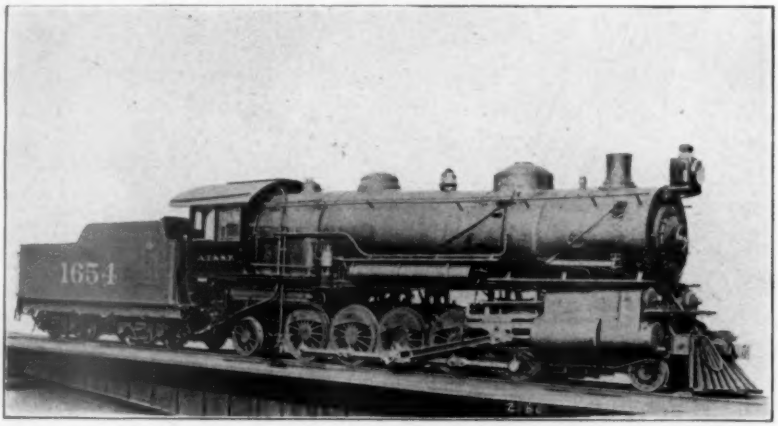


Fig 9. Tandem Compound Santa Fe Type Locomotive.
Atchison, Topeka and Santa Fe Railway

pistons are mounted on the same piston rod. Each cylinder is fitted with a piston valve. The two valves on the same side of the engine are driven by one valve stem, which is actuated by the Stephenson link motion. The weight of this engine is approximately 287,000 pounds, of which the driving wheels carry 234,000 pounds. The tractive power is 62,700 pounds.

The next cut represents one of the largest locomotives thus far completed in the experience of the Baldwin Locomotive Works. This engine is one of five Mallet compounds, built for the Great Northern Ry. Co. in 1906. It is representative of a type which, for some time, has been used in various parts of the world on lines having heavy grades and sharp curves. The re-

cent introduction of the Mallet type into American practice, is the result of a demand for a locomotive having exceptional tractive power and, at the same time, ample flexibility. The driving wheels are divided into two groups. The high pressure cylinders drive the rear group, and the low pressure the forward group. The rear frames are in rigid alignment with the boiler. The front group of wheels practically constitutes a truck, the forward frames being pivoted to the rear frames. The fulcrum is located on the centre line of the engine, between the high pressure cylinders. The latter receive steam from the throttle valve located in the steam dome, through external, rigid pipes. The exhaust

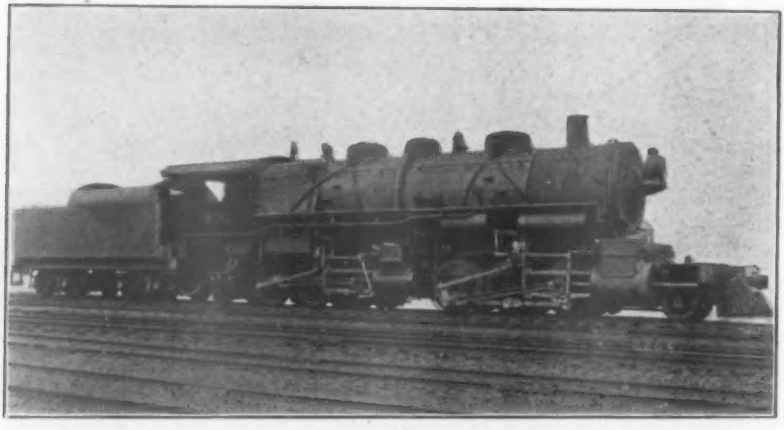


Fig. 10. Mallet Compound Locomotive. Great Northern Railway

steam is conveyed from the high pressure to the low pressure cylinders through a receiver pipe having flexible joints, so that it can accommodate itself to the swing of the forward group of wheels. A flexible exhaust pipe connects the low pressure cylinders with the smoke box. As these pipes carry only low pressure steam, there is practically no difficulty in keeping the joints tight. To give better curving qualities and reduce the flange wear on the driving wheels, the locomotive shown is provided with a two-wheeled radial truck at each end.

The cylinders of this engine are 21½ and 33 inches in diameter by 32 inches stroke. The driving wheels are 55 inches in diameter, and the steam pressure is 200 pounds per square inch. The tractive power is thus 71,700 pounds, and as the weight on

the driving wheels is 316,000 pounds, the ratio of adhesion is 4.4. The drawbar pull of this locomotive is sufficient to lift against gravity, a passenger engine of the type ordinarily used thirty years ago.

The Walschaerts valve gear is applied to each cylinder, and reversing is effected by a McCarroll reversing engine driven by compressed air. Balanced slide valves are used throughout. The boiler measures 84 inches in diameter and contains 5658 square feet of heating surface. The fire box is of the Belpaire type, with 78 square feet of grate area. The weight of the engine alone is 355,000 pounds, and the combined weight of the engine and tender 503,000 pounds.

While it may be questioned whether a locomotive of this capacity is suitable for regular road service, it is of unquestioned value for pusher service on heavy grades. It has practically the power of two ordinary locomotives. The weight is well distributed over a long wheel base, which, however, is sufficiently flexible to enable the engine to round 16° curves. This is a feature of importance in mountain service, where sharp curves are usually frequent.

The types of locomotives which have been illustrated are sufficient to show, in a general way, the trend of modern practice. With the enormous volume of traffic which the railway companies are to-day required to handle, it is almost imperative that each new lot of locomotives be more powerful than its predecessors. Under present conditions a backward step as far as power and capacity are concerned, can scarcely be considered.

But to what is this constant progression tending? and when will the limit be reached? Several Mallet compound locomotives, which will be more powerful than any that have preceded them, will shortly appear. According to the technical press, these engines will have a tractive power of 98,000 pounds, which they will develop in regular road service. The fire grate area will be 100 square feet. The fire box will be as wide as the loading gauge permits, and of maximum length consistent with good firing. It is safe to say that about three tons of coal per hour is the limit which can be handled by a fireman. To burn this amount in the locomotive under notice, the consumption per square foot of grate will be only 60 pounds per hour. This is a low rate for a locomotive, and it could doubtless be considerably increased,

provided a satisfactory method could be found for getting the coal into the fire box.

The tests which were conducted by the Pennsylvania Railroad on the St. Louis testing plant furnish interesting data from which the probable maximum horse-power that can be developed by the steam locomotive may be estimated. These tests indicate that the locomotive is by no means the wasteful machine that it is often thought to be. The two single expansion engines tested showed a minimum steam consumption of about 24 pounds of water per horse-power hour, when cutting off at approximately one-third stroke. Six compound locomotives were tested, and under economical conditions of working, their steam consumption was less than 20 pounds per horse-power hour.

If, now, it is assumed that the average evaporation per pound of coal is 7 pounds of water (which is a high value for much of the fuel used in locomotive work), and that the water rates are as stated above, the fuel consumptions for single expansion and compound locomotives will be respectively 3.43 pounds and 2.86 pounds per horse-power hour. If the maximum amount of fuel that can be handled is 6,000 pounds per hour, the single expansion locomotive can, under these conditions, develop 1750 horse-power, and the compound 2100 horse-power. These very high powers were not reached on the testing plant, but it seems not unlikely that they have been attained on the road under favorable conditions. The speaker, on at least one occasion, has traveled over an approximately level road for a distance of 30 miles at an average speed of 80½ miles per hour. According to the usually accepted formulas for train resistance, the horse-power required for this performance was about 2300, and this was maintained for 22 minutes. The locomotive had single expansion cylinders, and the coal consumption, based on the figures previously given, would be at the rate of nearly 7900 pounds per hour.

There is no way of absolutely verifying the figures just quoted, and they may be too high; but they serve to show that, if the power of the locomotive is to be further increased, the fuel and water consumption per horse-power hour must be materially reduced, or the firing must be mechanically performed. The compound locomotive has shown its ability to develop more power per ton of weight than the single expansion engine, and its in-

creasing use in the future may be expected. The balanced type is the most promising for high speed service, while for slow and heavy freight service the Mallet type seems particularly suitable. Radical changes in design, such as the introduction of the water tube boiler, for example, are by no means beyond the limits of possibility; while superheated steam may play an important part in the solution of the transportation problem.

When the electric locomotive displaces the steam machine in regular road service, it will do so, not because of its increased economy, but because of its ability to perform work which the steam locomotive cannot accomplish. Even at this early period in its development, its ability to accomplish this result has been practically verified.

There is no doubt that the further development of the steam locomotive will be accompanied by the more extensive introduction of refinements in design and construction, tending to improve the efficiency of the machine. This will necessitate better shop and round house equipment, in order that the motive power may be properly maintained, and worked to best possible advantage. The problem of securing adequate transportation facilities in this country is most complex and exceedingly difficult of satisfactory solution; and during the years to come the utmost skill will be exercised, by the railway companies and locomotive builders, in developing the locomotive to the point of maximum efficiency.

PORTLAND CEMENT.

Portland cement, says the Boston *Commercial Bulletin*, has increased in popularity as a building material, not only in progressive countries, but the world over. In far-away India, for instance, it is already in general use, and its advantages are all the time becoming better understood. Wherever wood is used there for structural purposes it is laid in cement if possible, and floors, mouldings, cornices, and trimmings of sand and cement are common, both outside and inside. Houses that have flat roofs are covered with brick dust and particles of brick mixed with cement and packed down hard. Pitched roofs are covered with corrugated iron and then solidly covered with cement and sand. A few figures, perhaps, will best testify to the augmented and still constantly growing uses of cement in India. The imports in that country as long ago as 1870 were valued at $50,342, advancing in the fiscal year 1900 to 729,478 hundredweight, valued at $500,332, and in 1906 to 1,778,428 hundredweight, valued at $1,070,275.—*Eng. and Min. Jour.*

THE CABLE SYSTEM IN TELEPHONE LINE CONSTRUCTION.

The annual report of the American Telephone & Telegraph Company contains the following interesting paragraphs on progress and development in the telephone business:

The improvement in cables within the past few years has revolutionized the art of telephone line construction. Not only is it now possible to place in underground ducts cables containing 400 or even 600 circuits, but a pole line, the carrying capacity of which would have been exhausted by 40 pairs of open wires, can carry 600 pairs of wires in the form of cables. The old-fashioned exchange pole line rarely carried more than 20 pairs of open wires. Sound economy has many times in the past year required the scraping of all the wires on a pole line, cable being substituted for them as the only way of securing the enlargement of facilities required, and not unfrequently has it been necessary to reconstruct the whole line as the cheapest way of securing the opportunity for growth that was required.

If the very great development of the business could have been foreseen, and the engineers and manufacturers had at an early date solved the cable problem so that cables of large capacity could have been originally installed, instead of open wire, in places where a large number of circuits would ultimately be required, much money would have been saved.

Now that it is certain that the business will develop on lines of reasonable profit to an extent much greater than even the most enthusiastic telephone man ventured to expect a few years ago, it would be the height of folly not to anticipate the certain extension of the business by providing facilities for growth when they can be most economically installed.

The great extent to which the telephone business was sure to develop became apparent about the year 1901 when the number of new subscribers increased nearly 220,000, as compared with about 167,000, the largest increase in any prior year. The large increase in the number of subscribers through 1905 which was attended by an equally large increase in toll service, practically exhausted the plant of the Bell Company and involved rebuilding that plant to a large extent. The year 1906 has seen additions to construction which not only enabled the companies to take care of the 2,241,367 subscribers connected with the system on January 1, 1906, and the nearly 500,000 added during the year, but which resulted in plant conditions which will enable future growth to be taken care of with economy. Constant additions will have to be made to the plant, but they will largely be on predetermined lines, utilizing, extending and rounding out the systematic plant conditions that now exist.—*Iron Age.*

THE FRENCH Government has decided to use the Eiffel Tower as part of the army wireless telegraph system. Using it in the last army maneuvers, the War Department was able to maintain communication with the Eastern frontier along the Vosges, and since then the tower station has communicated with London and Berlin. New installations are being made for maintaining regular communication with Algeria and Tunis.—*Iron Age.*

(Stated Meeting held Wednesday, March 20th, 1907.)

Ozone: Its Nature, Production and Uses.

JAMES HOWARD BRIDGE.

"There is no discovery in modern chemistry that is more important than that of ozone," wrote Frémy, the French scientist, a generation ago; and to this the illustrious Bunsen joined the prediction: "When we shall be able to produce it industrially, hundreds of new applications will arise."

Recent developments in electrical science have been so sensational that the quiet emergence from the laboratory into commercial use of this new agent in industry, sanitation and therapeutics, has been unmarked by any save the few experts who have wrought the change. Our admiration has been challenged by spectacular feats in wireless telegraphy and the like; and the evolution of new manufactures, the application of perfected sanitary processes, the establishment of new therapeutic principles, made possible by the fulfillment of Bunsen's prophecy, have received a few casual notices in technical publications, which have promptly dropped into the oblivion of the files of public libraries.

The Nature and Properties of Ozone.—Ozone is a form of oxygen, which, by readjustment of its molecular structure, has acquired new physical and chemical properties while preserving its original elemental character. A molecule of oxygen consists of two atoms, and in physics the element is written O_2. Ozone has three atoms to the molecule and is written O_3. This extra atom endows ozone with special powers which differentiate it from ordinary oxygen. The differences have been tabulated by the French chemist, Houzeau, as follows:—

Properties of Ozone + 15°.	Properties of Oxygen + 15°.
A gas with strong odor, and a flavor of lobster.	A gas colorless, inodorous, tasteless.

Comences to decompose at about 100° C.	Very stable at all temperatures.
Strong oxidizing agent.	Feeble oxidizing agent.
Decolorizes blue litmus.	Without action on blue litmus.
Rapidly decomposes potassium iodide, liberating the iodine.	Does not decompose potassium iodide.
Rapidly oxidizes ammonia, and transforms it into nitric acid.	Without action on ammonia.
Decomposes hydrochloric acid, liberating chlorine.	Does not react on hydrochloric acid.
Combines with phosphoretted hydrogen with emission of light.	Without action on phosphoretted hydrogen.
Oxidizes silver.	Does not oxidize silver.
Corrodes India rubber and cork.	Does not corrode India rubber nor cork.

Faraday enumerated some of its powers in a lecture delivered as early as 1851 before the Royal Society, as follows:—

"Ozone destroys many hydrogenated gaseous compounds; the combinations of hydrogen and sulphur, selenium, phosphorus, iodine, arsenic and antimony are thus affected. It appears to unite chemically with olefiant gas, in the manner of chlorine.

"It instantly transforms the sulphurous and nitrous acids into sulphuric and nitric acids, and the sulphites and nitrites into sulphates and nitrates. It changes many metallic sulphurets (as those of lead and copper) into sulphates. Like chlorine, bromine and the metallic peroxides, it is a powerful electromotive substance.

"It decomposes many iodides in their solid and dissolved state; by its continued action, iodide of potassium becomes converted into iodate of potassa.

"It changes both crystallised and dissolved prussiate of potassa into red salt, potash being evolved.

"It discharges vegetable colours with a chlorine-like energy.

"It produces oxidizing effects upon most organic compounds, causing a variety of chemical changes; thus guaiacum is turned blue by it.

"From the above enumeration, it would appear that ozone is a ready and powerful oxidizer, and, in a great number of cases, acts like Thénard's peroxide of hydrogen or chlorine and bromine."

The real character of ozone, however, was not known even to Faraday at this date, when the new gas was variously regarded

as hypo-nitric acid, volatilized metallic matter, peroxide of hydrogen, a new element, etc., etc.

Van Marum was the first to notice, in 1783, that by passing electric sparks through a tube containing oxygen, the gas acquired a distinct odor and abnormal oxodizing properties. Cruickshank, in 1801, noticed a similar smell during the electrolysis of water; and Cavallo, soon after, reported that "electrified air" had a purifying effect on animal and vegetable matter, when in a state of decomposition, and employed it as a disinfecting application to foetid ulcers. Cavallo spoke of this condition of the air as the "aura electrica." In 1826 Dr. John Davy (Lectures on Agricultural Chemistry) recognized the existence of this principle in the atmosphere, and published a formula for the preparation of chemical tests to be used in its detection, resembling that afterwards adopted by later investigators. The discovery was then allowed to lie inert until 1840, when the Swiss chemist, Schönbein, observed afresh the peculiar smell proceeding from one of the gases liberated on electrolysis of water. This he recognized as having some similarity to the "aura electrica" developed on the points of an electric machine; and he gave it the name Ozone, from the Greek verb "to smell." The discovery was communicated to the scientific world in a paper to the Munich Academy of Science, and immediately gave rise to numerous controversies concerning the nature and properties of the gas, controversies which lasted many years. Schönbein at first believed it to be a new electro-negative element belonging to the same class as chlorine and bromine. Then he thought it might be one of the constituents of nitrogen; and later he believed it to be a combination of hydrogen and oxygen; and he so wrote to Faraday. In 1845 de la Rive and Marignac asserted that, under the influence of the electric spark, dry oxygen yields ozone; therefore, ozone is nothing but oxygen brought to a peculiar state in which the gas possesses properties which it has not in its natural state. This was combatted by other scientists, including Schönbein himself, who now declared ozone to be peroxide of hydrogen. In 1849 Leuch, representing ozone as galvanized air, O*a*, first made mention of its industrial use "as the most powerful bleaching agent." About the same time Schönbein sent to Faraday a letter written with a manganese sulphate solution, which had turned brown under the action of ozone. He

also announced the re-discovery of Dr. Davy's test to ascertain the presence of ozone by starched iodide of potassium, which is the test applied to-day. Other investigators like Baumert, Becquerel, Faraday, Dr. Hare, of Philadelphia, Frémy, Le Blanc, Andrews and Houzeau took up the subject during the next few years, gradually revealing the properties and constitution of the new gas, until, in 1856, Dr. Andrews, of Edinburgh, confirmed de la Rive and Marignac by showing that "ozone from whatever source derived is one and the same body, having identical properties and the same constitution, and is not a compound body, but oxygen in an altered or allotropic condition."

The Production of Ozone.—The ozone made by early investigators was generally obtained by chemical means. Numerous reactions result in the production of O_3. The most common, and that generally employed prior to the invention of means for controlling the effects of the electric discharge, was the slow oxidation of phosphorus. This is achieved by very simple means. Oxygen diluted three times with air, or ordinary atmospheric air, is drawn by aspiration across the surface of water in which sticks of phosphorus are half immersed. The resulting gas when washed is dilute ozone. At freezing point the production of ozone is nil; but between 15° and 20° C. it is very abundant. The confusing results of early experimenters with ozone were largely due to this method of production; for the ozone was never obtained pure, being more or less mixed with phosphoric acid.

Under the influence of light, and in contact with air, turpentine is oxidized and gives off feeble quantities of ozone, with formation of acids and resinous matters. Other hydrocarbons, coal-tar, various essential oils as those of eucalyptus, lavender, citron, etc., possess analogous properties.

Troost and Hautefeuille report having produced ozone by heating oxygen to 1400° C. to 2200° C. in a porcelain tube; and the statement has been repeated by almost every writer on the subject. It is certain that their observations were defective. It might be inferred *a priori* that, at such temperatures as those stated, any ozone formed would be instantaneously destroyed so as to render its detection impossible. This inference has been confirmed by Mr. J. K. Clement who has made a series of careful experiments in this direction at high temperatures. His results are published in Annalen der Phys., IV, Folge, Vol. 14. 1904.

page 334. He conducted a stream of pure oxygen over the surface of an incandescent Nernst filament, so that it was heated to about 2200° C., while, when streaming away, it was quickly cooled. He could not detect any formation of ozone, nor was any found at the temperature of the arc lamp, about 3000° C. Whenever there were traces of nitrogen present, NO_2 was formed, which, in its reactions, is very similar to ozone; and it seems to be due to this fact that the former investigators thought that ozone had been formed. Clement also gives the results of extended researches on the speed of disintegration of ozone. On the basis of a formula of van't Hoff which can be applied to this case, he finds that at 1,000° C. the content of ozone decreases in 0.0007 second from 1 per cent. to .001 per cent; this means that if ozone is really formed at a temperature of 2200° C. or more, it must disintegrate almost instantaneously when cooled even very quickly.

O. Loew, in New York, in 1870, "blew a strong current of air through a tube into the flame of a Bunsen burner and collected the air in a beaker glass or balloon." "I was thus able," he says, "in a few seconds to collect enough ozone to readily identify it by its intense odor and the common tests." This is another case of inaccurate observation.

Dr. J. K. Boeke, passing oxygen through the luminous flame of a Bunsen burner, found that the peculiar odor and the property of coloring the iodine starch test which were acquired, were due to the production of a compound of oxygen and nitrogen, probably the dinitric trioxide or nitric dioxide.

Oxygen is transformed into ozone under the influence of various radio-active bodies. This suggests a relationship with the chemical rays of the spectrum. If radium is enclosed in a tube filled with oxygen, ozone is formed inside the tube; but if the radio-active substance is sealed in a separate vessel no action takes place on oxygen brought within the influence of the rays proceeding from it. From this fact M. and Mde. Curie came to a notable conclusion, viz., that the transformation of oxygen into ozone required the expenditure of active energy, and that the production of ozone under the direct rays of radium proved that these radiations represented a continuous liberation of energy.

A further deduction may be made: the walls of an ordinary

tube do not permit the passage of ultra-violet rays; therefore there is no action on the surrounding gas. A quartz tube, which is pervious to the ultra-violet rays, would probably yield other results.

Ozone may be produced by numerous chemical reactions, as, for example, that of monohydrated sulphuric acid on bioxide of barium. At a temperature below 75° C. there is produced at the same time hydrogen peroxide.

Kindred results are obtainable with the peroxides of zinc and magnesium on sulphuric acid and with the alkaline peroxides of sodium and potassium. Ozone probably plays some part in the bleaching properties exhibited by these compounds in industrial uses. Permanganate of potash lends itself to similar reactions, but its manipulation requires care to avoid dangerous explosions. The persulphates of potassium, sodium, barium, ammonium, etc., may be decomposed with liberation of O_3, a fact utilized in various industrial applications.

Of all chemical reactions by which ozone is produced, that of fluorine in water is the most promising, an ozone-concentration in oxygen of upwards of 14 per cent. having been obtained in half an hour. If fluorine can ever be made cheaply, its use in the production of ozone may become important by reason of the purity and richness of the gas made possible by its means.

Ozone is also produced by the decomposition of water by the electric current. This, indeed, led to its re-discovery by Schönbein. The process is aided by adding acid to the electrolyte. The electrolysis of acidulated solutions of potassium permanganate yields more ozone than does the electrolysis of acidulated water; but neither process has any commercial interest or value in comparison with the perfected electrical methods in use, now to be described. The highest yield of ozone reported of electrolytic processes is 3 grams per K. W. hour of energy expended.

The neutralization of two opposite charges of electricity known as an electric discharge, produces a variety of effects when it takes place through a separating body of oxygen or atmospheric air. These effects are luminous, heating, chemical, mechanical and magnetic. Most of them do not concern us here. In ozone production it is the chemical action which is sought; and the luminous, heating and other effects are accidental and often undesirable accompaniments.

A discharge may take place in any of several forms, chiefly, the arc, the spark and the glow. The arc-discharge is accompanied by the production of light, intense heat and energetic chemical action, especially on the nitrogen of the air, which, in the presence of moisture, it converts into nitrous and nitric oxides. The spark, or disruptive discharge, has similar chemical and heating properties, but gives out less light. The glow or silent discharge has little light, less heat and, in air, acts almost exclusively on its oxygen. Only when moisture is present

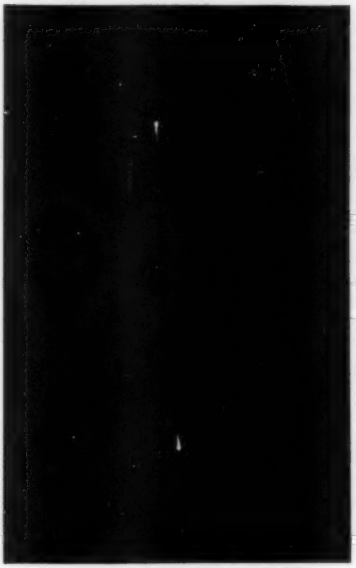


Fig. 1. Showing a small arc-discharge.

does it act upon nitrogen, and then only in a very small degree as compared with the other forms of discharge.

Figure 1 is a reproduction of a small arc from an alternating current transformer. It may assume a length of several feet, is characterized by a humming sound, a flame-like shape ever changing, and, as already stated, produces an intense heat. It is a continuous discharge of great current strength, and hence of great danger to the life of the apparatus.

Figure 2 is a spark discharge. It is a yellow-white, zigzag, loud snapping, oscillatory discharge. Figure 3 is a photograph

taken of 10 consecutive sparks from a static machine, as shown in Figure 2.

Figure 4 is a spark from a Rumpkorff induction coil operated by a high frequency interrupter. It is a mixture of the spark and violet brush discharge previously spoken of as the glow.

Figure 5 is the glow or silent discharge. It is characterized by a dark blue violet color. It is a convective discharge, unidirectional from positive to negative.

Figure 6 is the same kind of a discharge proceeding from the negative pole of a static machine. It may be noted that this form of discharge, whether proceeding from the positive or the negative pole, assumes an essentially cone-like shape with a hollow interior. Recognition of this fact has recently wrought important changes in the art of ozone production. This violet-colored discharge is the only one by which ozone may be continuously produced with any practical degree of purity.

The theory has recently been advanced, and is now gaining pretty general acceptance, that the formation of ozone by the brush or silent discharge is caused, not by any direct electrical action on the oxygen itself, but is simply a photo-chemical effect, due to the ultra-violet rays accompanying such discharges.

This theory, which seems destined to revolutionize our conceptions of ozone-formation, originated with the discovery of Lenard, who noticed that if the light from a spark gap was allowed to pass through quartz plate, which is transparent to ultra-violet rays, and to impinge on oxygen, ozone was generated. If, however, a substance impervious to ultra-violet light was interposed, no such action took place. Goldstein followed up the discovery by showing that the ozone odor existed on the outside of Geissler tubes through which a discharge was passing, only, however, if the tubes were partly of quartz. Warburg then announced that ultra-violet light and cathode rays accompanied the discharge in a Siemans tube; and with the assistance of Regener he showed by volumetric tests that, in addition to the ozonizing action of the rays, a deozonizing action was at work, and that the relative rapidity of the two processes was fixed. Fischer and Braehmer advanced the discovery a step, when experimenting with a quartz mercury-vapor lamp rich in ultra-violet rays, they found the chief factors determining the process to be the temperature of the gas, the light intensity of the lamp, the rapidity

of the stream of oxygen and its purity. In their experiments the temperature of the lamp, without cooling, went to 270° C., at which of course ozone does not exist; but by lowering the tem-

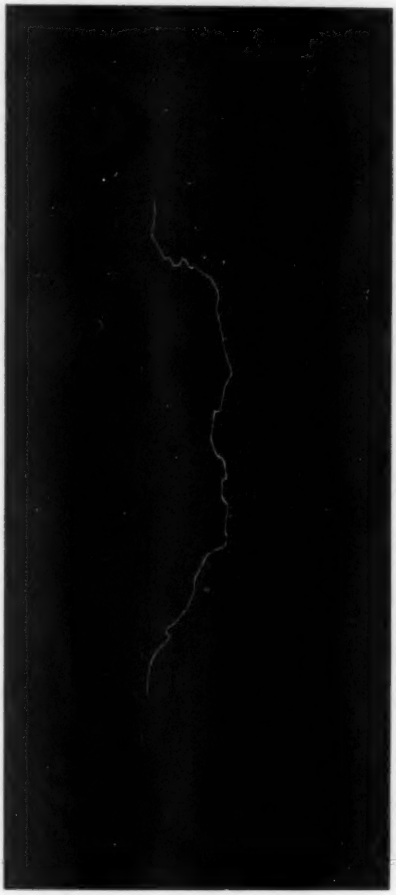


Fig. 2. A spark-discharge.

perature, the yield of ozone underwent a gradual increase. By maintaining the low temperature and increasing the intensity of the light, higher yields of ozone resulted. As the concentration increased, the yield diminished. Thus:

Per Cent. O_3.	Milligrams O_3.
0.192	0.571
0.201	0.593
0.234	0.540
0.230	0.528
0.249	0.382
0.259	0.382

By doubling the current the ozone generated was also nearly doubled.

This interesting theory has received collateral support from the investigations of Franz Richarz and Rudolph Schenck, who have pointed out the analogy between radio-activity and the behavior of ozone. They have shown that freshly prepared ozone, or ozone that is being decomposed under the influence of de-ozonizing agents, accelerates the condensation of water vapor. The presence of gaseous ions to which this phenomenon points, is further indicated by the considerable conductivity exhibited by ozone. In respect to this ability to produce gaseous ions, ozone is similar to radium and other radio-active substances. Further, a current of ozonized oxygen is said to cause a zinc sulphide screen to floresce, although barium platinocyanide and zinc oxide are unaffected. Red phosphorus, inert in oxygen, shows luminesence in ozone. Another point of analogy is the fact that radium salts and ozone both decompose with considerable development of heat.

In its simplest form an ozonizer consists of two metallic bodies separated from each other by a short gap, across which a current of electricity may be passed, in the form of a blue-flaming discharge, from one metallic body or electrode to the other. The electrification of the air in the path of the discharge produces the molecular changes involved in the conversion of O_2 into O_3.

This so-called silent or ozone-making discharge may be produced in several different ways. The earliest mechanism employed for this purpose was a static machine. This also gave off sparks, which, as stated above, in moist air, resulted in the formation of nitrous products which, mixed with the ozone, led to confusion in the minds of early investigators as to the real nature of the gas. A current from a battery of cells may be passed through an induction coil furnished with an interrupter;

and this will give a small but steady and efficient ozone-making discharge. The direct current from a dynamo may also be used if passed through a similar coil. It is, however, the alternating current from a dynamo of high periodicity, stepped up to several

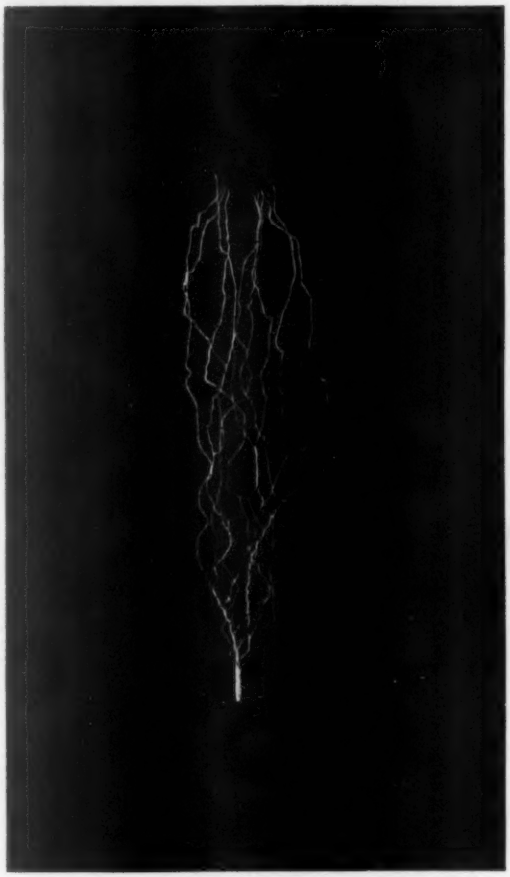


Fig. 3. Sparks from a Static Machine.

thousand volts, which offers the best means of obtaining the silent discharge; and this is the means in general commercial use to-day. Such an apparatus, however, may give any one of the three kinds of discharge described. The arc discharge by its intense heat destroys the apparatus, while the spark discharge

transforms the nitrogen of the air, mixes it with the transformed oxygen and gives impure ozone. Means must, therefore, be taken to prevent these undesirable forms of discharge, and to limit the apparatus to the production of the silent effluvium which transforms the oxygen of the air into its allotropic condition. To attain these ends the inventive faculties of all the investigators in this field have been directed for many years.

It was early discovered in the art that when a non-conducting substance like glass, mica or vulcanite, was placed between the poles of an electric machine, across the path of the current, the formation of sparks and arcs was prevented, and the current assumed the form of a silent blue discharge, which produced large quantities of ozone, varying in strength and amount with the tension and flow of the electric current. As this tension, or mechanical stress, requisite to overcome the resistance of the air as well as of the dielectric was necessarily very great, it frequently happened that the interposing glass or mica body was fractured under the strain, and before the current could be turned off an arc was formed which destroyed the mechanism. Efforts were therefore made to eliminate the dielectric; and many years of experiment and large sums of money have been expended in devising means to this end.

As regards the various yields of existing types of ozonizers, the differences in methods of testing render comparisons unreliable; and, until a uniform method is applied to determine the ozone-content of a given body of gas, no exact comparison can be made between the efficiency of the different types of apparatus now in use.

The Siemens & Halske ozonizer, with dielectrics, is reported to yield 20 to 30 grams per K.W. hour. Elworthy claims 60 to 70 grams from a machine of similar construction; but no data are available as to the richness in ozone of this product. Otto has published figures showing yields of 20 to 118 grams per K.W. hour, the former where the concentration was .852 grams per cubic meter of air, and the latter where it was only .542. Vosmaer with a concentration of 1.5 obtained a yield of 12 to 16 grams. The de Fries apparatus produces about 20 grams with a concentration of 1.0. Generally speaking, 20 grams has hitherto been considered a fair output if the air treated contains one gram and upwards of ozone per cubic meter.

A very noteworthy increase in the efficiency of ozonizers has recently resulted from a simple observation made by the author. Reference to the photographs of the silent discharges printed on pages 369 and 371 shows that these are cone-shaped funnels. They may be conceived as hollow cones of light. In all ozonizers

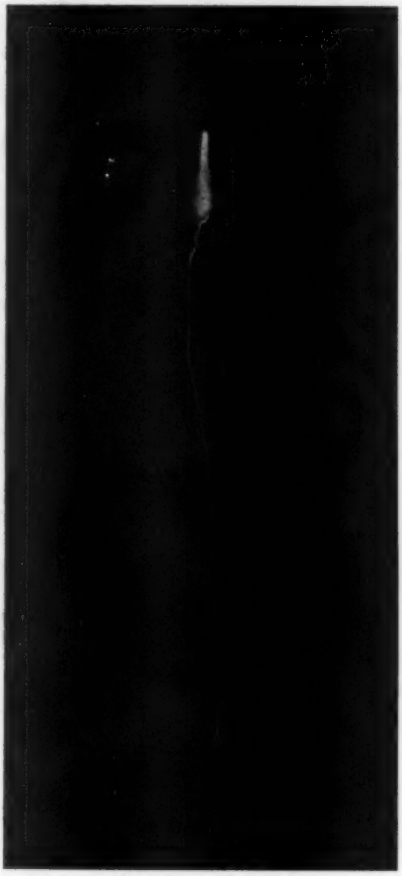


Fig. 4. Spark from an Induction Coil.

hitherto devised, the air is directed against, or around, these cones of light in a plane at right angles to them. Now it is a well known fact that when electricity is discharged from a point, the surrounding particles of air are electrified, and, being of the

same electrical sign, repulsion takes place. The currents of air repelled from the points of a discharging electric machine may be felt by the hand, or seen in the deflected flame of a candle held close to them. The well known electrical toy, called Hamilton's Mill, rotates because of this repulsion of the electrified air from the discharging points. With these facts in mind, it is obvious that air, when passed into the influence of a discharge at right angles to its path, is immediately thrust away from it, and any effect which the discharge may have on it is but momentary. This is an obvious disadvantage where it is sought to bring about that molecular readjustment in the particles of air submitted to electrification which accompanies their conversion into ozone.

To overcome these disadvantages the writer has devised a perforated electrode, and so arranged the air supply that it passes through the perforations in fine streams directly into the hollow cores of the discharges taking place on its surface. In this way the air is forced to travel first upwards with the discharge, while completely surrounded by it, and then forced through the luminous walls of the discharge. This brings every particle of the air into intimate contact with the discharge. The first tests of the apparatus gave 80 grams of ozone of a high concentration. The principle, thus proved so revolutionary, has been recognized as novel in the art by the patent offices of America and Europe.

An extension of this principle, which logically follows, is that by which the treated air is instantly led away from the deozonizing effects of the heat of contiguous discharges by withdrawal through the perforations of an opposing electrode. In this way air first passes directly into the core of a discharge taking place from one electrode, which, for convenience, may be called the anode, and is thence led directly into the core of a second discharge taking place from the opposing electrode or cathode, and so passes at once out of the influence of the discharges through the cathodic perforations. Of course, this can only be done when no dielectric is placed between the dischargers; and arcing and sparking must then be prevented by employing the usual resistance in the circuit between the source of energy and the discharge.

Ozone in Water Purification.—Considerable difference of opinion exists among experimenters concerning the minimum

concentration of ozone requisite for the effective sterilization of water. Tests have been made in Europe with concentrations as low as 0.5 gram per cubic meter of air and as high as 15 grams. In each case satisfactory results have been achieved, as shown by bacteriological tests. Indeed, as low as 0.3 was found effective by Professor Van Ermengem in tests made at Brussels. At Gennekin, Schneller has successfully used concentrations as low as .537. At Rotterdam, Van Delder, using the Vosmaer system, obtained satisfactory results with an average concentration of .8;

Fig. 5. Silent-discharge from positive pole of a Static Machine.

and Professor Proskauer, at Berlin, found .9 to 1.8 efficient. The following is an extract from the report of tests of the de Fries plant near Paris made by the official authorities of that city:—

Concentration.	Air per M_3 of water in cubic-meters.	Total ozone per cubic meter of water.	Bacteria Before ozonization.	Bacteria After ozonization.	In the collecting tank.
1.6	1.383	2.216	800	2	4
1.04		2.035	850	3-4	
.98	2.077	1.352	2682	3	

.88	1.537	2.04	3732	7	
1.	1.003	1.	2886	9	
.835	1.003	0.693	2886	45	
1.12	1.037	1.61	4445	14	9
1.43	0.831	1.188	145	2	1

At Weisbaden and Paderborn, Germany, the Siemens & Halske apparatus in use there show the following results:—

Concentration in grams of ozone per cubic meter of air.	Number of germs per c.c. Raw Water.	Ozonized Water.
1.4	39,000	8
1.7	26,000	12
1.6	55,000	5

At Philadelphia, during a protracted series of tests during the year 1905, the following results were achieved with low concentrations:—

Concentration.	Oxygen consumed. Before.	After.	Air in cubic feet.	Water treated. Gallons.	Bacteria. Before Ozonization.	After Ozonization.
.7	1.34	.37	4950	12800	12500	19
.64	.74	.57	5020	37500	4600	200
.68	1.01	.97	4800	37000	600	60
.35	1.06	.83	4840	35400	160	11
.49	1.77	1.03	5010	20200	75	10
.6			4930	20000	5400	15
.78			3045	29700	170000	42
.83			3080	30500	130000	70
.87			4196	28200	80000	34
.47			4196	31800	1200	20
.62			3113	30650	73000	250
.91			2775	29100	1800	9

The quantity of ozone absorbed varies with the amount of organic matter contained in the water. In distilled water ozone is but slightly soluble. Nor does the number of bacilli present in water make any preceptible difference in the amount of ozone absorbed; for however great their number may be, they represent an infinitesimal weight of organized matter to be consumed. Otto finds the ozone absorption of waters treated by him to vary between 0.5 gram and 0.8 per cubic meter of water treated, and asserts that these figures are corroborated by tests made by Dr. Erlwein at Weisbaden. Similarly, at St. Maur, Mr. Van der Made, engineer to the Sanudor Co., told the writer he had found

that about half a gram of ozone is absorbed in the sterilization of a cubic meter of river Marne water after rough filtration.

The unutilized ozone is withdrawn from the surface of the sterilized water by Otto, de Fries and Siemens & Halske, and passed in continuous, successive cycles through the ozonizer and sterilizer. In this way they claim to save about two-thirds of the ozone produced. In the Howard-Bridge method the unabsorbed ozone is drawn from the treated water by the suction action of another current of water running rapidly down a U-shaped tube, sunk deeply into the ground. Here it is all used up in the preliminary oxidation of organic matter, so that when fresh ozone is added to this water the ozone is free to act with its primal

Fig. 6. Spark-discharge from negative pole of a Static Machine.

strength upon the bacteria. In the Vosmaer system the excess of ozone is allowed to escape into the air.

A number of mechanical means have been devised for mixing the sterilizing gas with the water under treatment. The one most generally used consists of a tower, sometimes filled with stones or other inert matters over which the water trickles and meets the ozonizing gas forced into the tower at the bottom. This is the column invented by Gay-Lussac and called by his name. It was used by de Meritens, the pioneer in ozone sterilization, and adopted by Siemens & Halske in their installations at

Weisbaden and Martinikenfelde near Berlin. It is a simple and efficient means of mixing the sterilizing gas and water. Analyses by Dr. Erlwein of the water before and after purification, covering a period of several days, yield the following reports:—

Bacteria per c.c. before Purification.			Bacteria per c.c after Purification.		
Maximum.	Minimum.	Average.	Maximum.	Minimum.	Average.
200,000	2,300	80,000	34	0	8

All pathogenic germs were destroyed. The amount of ozone used per cubic meter of water treated was 1.3 grams.

According to Dr. Erlwein, the cost of this process per cubic meter of water (264.17 American gallons) for a plant treating about 250 cubic meters per hour is 2 pfennigs or half a cent.

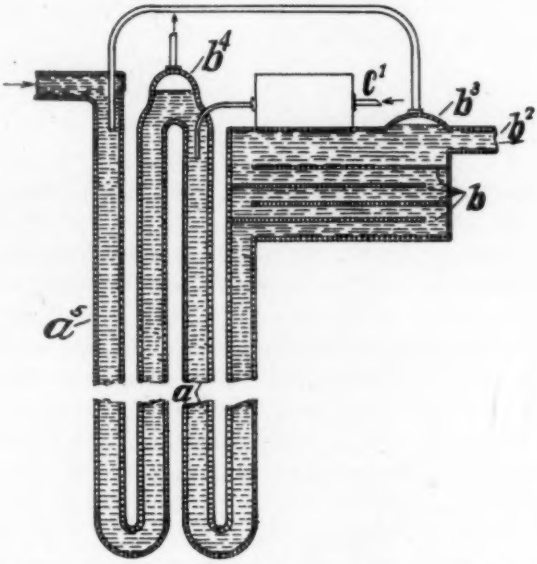
In American equivalents this is at the rate of $18.92 per million gallons in a plant capable of treating about 60,000 gallons of water an hour. Dr. Erlwein estimates that for a similar plant of 10,000,000 gallons a day capacity, the cost of operation would be about $7.00 per million gallons.

In the de Fries system the water and ozonized air are mixed in vertical cast iron cylinders enamelled inside. The water and air are introduced at the bottom and leave the apparatus at the top. The cylinders are divided into compartments by horizontal celluloid trays perforated with numerous small holes. On passing through these perforations the water and air are brought into close contact.

The operation of these and other systems involves the use of an air compressor for forcing the ozonized air into the column of water. As seen in Dr. Jackson's report on the Vosmaer tests, this required 4.4 H.P. hours for the treatment of 25,650 gallons. This is at the rate of about 160 H.P. hours or 110 K.W. hours per million gallons treated. In addition to this expenditure of energy, there are other disadvantages inseparable from this method of mixing the air and water. Ozone has such active oxidizing properties that ordinary lubricants cannot be used in the cylinder of an air compressor. The rings of the piston must, therefore, fit so tightly that if air is passed through the cylinder containing the least moisture, the machine either works with great difficulty and loss of power, owing to the swelling of the piston rings, or else stops entirely.

This difficulty is overcome, and a large part of the cost of

operating an air compressor is saved, by the Howard-Bridge process of causing the suction action of the water under treatment to draw into itself the ozonized air required for its purification. This principle is roughly shown in the accompanying drawing, which also illustrates the further advantage already mentioned, in that the excess of ozone which remains unabsorbed, and which in some systems is run to waste, is here utilized in the prelimin-



Raw water enters the pipe a^5 drawing, by suction, unabsorbed ozone from b^3. The waste gases escape at b^4. The current of water in a sucks fresh ozone into itself from the ozonizer c; and after passing around the baffle plates in b, the purified water escapes at b^2.

ary treatment of the water. By this system municipal water supplies can be sterilized at one-half the cost of slow sand-filtration, which never wholly removes bacteria.

The Industrial Uses of Ozone.—The difficulty of obtaining ozone continuously and economically, and of practical strength, has prevented its general adoption in those industrial arts to which it was found by early investigators to be theoretically applicable. Now that this has been overcome, and the gas can be produced in large quantities at slight cost, its application to

numerous manufacturing processes will probably no longer be delayed.

There are some compounds in nature and in intermediate stages of manufacturing that are comparatively worthless, which, if a single atom of oxygen were added to their molecules, would be transformed into products of greater value. Here is a theoretical illustration: Succinic acid is formed of four molecules of carbon, six of hydrogen, and four of oxygen. Add a molecule of oxygen, and malic acid results. Add still another and tartaric acid is produced. Thus:—

$$\text{Succinic Acid} = C_4H_6O_4$$
$$\text{Malic Acid} = C_4H_6O_5$$
$$\text{Tartaric Acid} = C_4H_6O_6$$

Ozone readily yields this additional molecule of oxygen to other elements or compounds, and this faculty may be utilized to add to their commercial value. Oil of cloves, for instance, has little value in comparison with the extract of vanilla bean; yet by ozonization it is converted into substance which for all practical purposes has taken the place of the natural extract, once so costly that it was stored in steel vaults. The writer was told by one of the inventors of this process that the entire cost of vanillin is only half the amount of the duty with which the Government of the United States has protected this infant industry. Vanillin, thus produced, is used for flavoring confectionery and ice cream from California to Maine.

Professor C. Harries, who has done excellent work in this new field of research, shows that "experimental results in ozonization lead to the conclusion that all organic compounds containing an ethylene linkage (double bond) add one molecule of ozone, giving rise to a new class of substances termed ozonides." "This method of work," he adds, "has already proved its value in permitting the comparatively easy preparation, in fairly large quantities, of many substances which were hitherto unknown, or could only be obtained with the greatest difficulty."

Sulphuric acid, which is the basis of many chemical industries, is made by simply ozonizing water containing sulphur. Whether this method can compete with existing processes, in which sulphuric acid is often a by-product, can only be determined by trial on a commercial scale.

One of the least expected applications of ozone is in the extracting of gold from its ores. This forms the subject of a serious paper by de la Coux in *Génie Civil,* February 14th, 1903, who says: "In treating auriferous minerals by solutions of hydrochloric acid submitted to the action of ozone, we have been able to obtain a rapid dissolution of the gold. There may be here," he adds, "a process capable of application in the treatment of auriferous minerals."

Peroxide of nitrogen is being made every day in flour mills in England by electric discharges. This is effected by subjecting ozonized air to a sparking discharge, which modifies the nitrogen of the air, and causes it to combine chemically with O_3 formed during the first part of the process.

The action of ozone on chromium is to convert it into chromic acid, which is extensively used in various industries, especially in tanning. The preparations of chromium sold to tanners bring a high price; and it is not unlikely that their manufacture can be cheapened by the new oxidizing agent.

Permanganic acid is formed from the prolonged ozonization of certain salts of manganese, which, contrary to the usual reaction, here lose a part of their oxygen. This may have no commercial value as yet; but the reactions of ozone on manganese are so numerous and interesting as to have excited some chemists to enthusiastic search for new combinations of the metal which may be found profitable. Oxides of zinc and lead are easily produced by means of ozone, but, perhaps, not so cheaply as by the electrolytic process accidentally discovered by the writer and brought to commercial completeness by Mr. Carlton Ellis. Metals, with the exception of aluminum, platinum, gold and perhaps one or two others of the very rarest of them, are readily oxidized by ozone, especially in presence of water. Here is a large field, as yet unexplored by the seeker for new industrial products.

In organic chemistry a wide vista of new industrial effects is opened through the agency of the new gas. Otto, to whom we owe so much of our knowledge of ozone and its properties, has produced formic acid and formic aldehyde from methane or marsh gas. Here we have the basis of a new tanning agent and a powerful disinfectant created, as it were, from nothing. By ozone iodoform has also been made by Otto from iodide of

potassium and alcohol, and the process is commercially practicable.

The bleaching and refining of mineral oils was one of the first industrial uses to which ozone was applied; but the cost of the gas prevented its development. This may now be changed. Otto has prepared from petroleum an ozonized jelly having strong antiseptic, parasiticidal and disinfectant properties, which he calls Petrole-Ozoné.

According to various experimenters, Mare, Ney and others quoted by de la Coux, camphor has been made by ozonizing turpentine; and the process gives promise of having commercial value.

Numerous methods have been devised, and patents taken out, for the bleaching and purifying of sugar and syrups by ozone; but these have hitherto failed owing to the difficulty of producing the gas. In these processes ozonization is generally assisted by electrolysis; and some striking results of the double action thus obtained are published by de la Coux. These are too long to reproduce here, but they may be summarized as follows:—

	Decoloration and increase in purity, Per cent.		
	By ozone.	By electrolysis.	By ozone and electrolysis.
Decoloration	35	75	95
Purity	8.5	21	36
Saline coefficient.....	10	27	137
Organic coefficient.....	14	31	47

The Philadelphia ozonizing plant has been investigated by the experts of one of the principal refining companies in the United States, but the results of their tests have not been made known.

The bleaching properties of ozone have been applied industrially to the whitening of wax, gum lacquer, ivory, bone, feathers and various other things, with more or less success. In the manufacture of linoleum it has been found of special advantage in that the oils successively applied to the cloth are quickly oxidized, so that the capacity of the factory is increased, while the incidental bleaching of the oils results in a brighter and cleaner-looking product. Similar results have followed its use in oxidizing the varnish on "patent leather," glazed kid and the like.

In the manufacture of starch ozone has been utilized as a

bleaching agent, and has led to an incidental product intermediate between starch and dextrine which, it is stated, is taking the place of gum arabic in the textile industries. Two large plants are said to be in successful operation in Germany, one at Kryitz and the other at Fuerstenwalde. This illustrates the unseen possibilities offered to investigators by the new oxidizing gas. So far as the writer knows, ozone has not been used in the manufacture of glucose. It is possible that its use would so modify the residues of the sulphuric acid employed in its manufacture, as to rid it of its injurious properties when used as a food.

In this connection Dr. Fröhlich, of Messrs. Siemens & Halske, in illustrating the bleaching properties of ozone, states that 20 grams of ozone per H.P. hour "will bleach 110 pounds of linen as well as grass bleaching during three days; it will in presence of chlorine, bleach and refine 88 pounds of potato starch to such a degree that the color becomes a clear white and the bad odor and taste are removed; if this is roasted and ozonization is continued a product resembling gum arabic is obtained; 20 grams of ozone being sufficient for 66 pounds of this product."

For the use of the tanner an excellent substitute for degras, an expensive softener of which the supply is constantly dwindling in proportion to the demand, has been produced by ozone from inexpensive oils. Here is a chance for the creation of a new and profitable industry.

Roscoe is said to have produced aniline from alcohol years ago; and the researches of Otto have shown, close to this field, a wide range of unexplored territory awaiting commercial development. In the synthetic production of indigo ozone may have an important role; as it has been found to possess in the preparation of artificial perfumes.

In a single month in 1903, the Société Francaise de l'Industrie Chimique produced 22,000 kilograms of vanillin by means of ozone, which at 35 to 45 francs has taken the place of a product that in 1895 was worth 800 francs. The German firms previously making vanillin synthetically are said, by de la Coux, to have closed their factories, and now buy their supplies in France. The method employed in France and at Niagara Falls is patented, and has yielded its owners enormous profits.

Other unexpected uses for ozone have been found in the hardening and ripening of wood for special purposes, such as musical

instruments, and, in striking contrast, in the stimulation of silk worms. In Paris, the linen from hospitals is disinfected by ozone and a large laundry in the St. Honoré market has long used the gas in this way. Other uses that have been suggested for it is the purification of illumination gas, the improving of cigars and tobacco—of which it is stated "the aroma and finesse are increased," the removal of undesirable odors from raw coffee, and the destruction of the phylloxera. These more or less doubtful suggestions may be omitted, and the actual applications already enumerated, will sufficiently indicate the wide and diversified range of the industrial uses to which this powerful oxidizing agent may possibly be applied.

Ozone in Therapeutics.—In 1887 Dr. Donatien Labbé, using a Houzeau vacuum tube, produced pure ozone by the silent discharge. This he found he could inhale in doses which had previously been considered injurious; and he thereupon commenced a series of experiments on tuberculous and anemic patients which for the first time fully established the high therapeutic value of the gas. In 1889 Dr. Huguet de Vars installed several ozonic sanitariums in Paris and in the south of France, where he is said to have cured his patients by means of ozone in inhaling rooms. In 1891 Dr. Labbé presented the results of his several years' experiments in the ozone treatment of tuberculosis, etc., in a paper read before the French Academy of Sciences. The curative effects set forth in this paper produced a profound impression on the medical world. Ozonizing apparatus were installed in several French hospitals; and in May, 1892, at the Lariboisière the wounds of the victims of the dynamite explosion at Véry's restaurant were bathed with ozonized water.

Upon the nutritive functions ozone inhalations have a stimulating effect. Perisalsis is markedly quickened, so much so that the characteristic griping sensations following the use of an energetic cathartic are sometimes experienced after a short inhalation. There is increased elimination of urea and phosphoric acid, which indicates a corresponding stimulation of the kidneys. Improved appetite accompanies and succeeds a prolonged series of ozone inhalations, and the fact, reported by nearly all investigators, that the iron constituents of the blood are increased, shows improved nutrition. Since the iron is not conveyed into the blood by the inhalations, it must necessarily be derived from

the food; and this indicates a more efficient working of the entire nutritive system.

The physiological changes thus indicated show that ozone may be advantageously used to correct the conditions producing anemia; while the increased elimination of urea and phosphoric acid found by Dr. Peyrou and confirmed by Drs. Labbé, Oudin and Caritzalis, may be considered as indicating possible beneficial effects of ozone in gout, rheumatism, diabetes, etc.

On the circulatory system ozone again acts as a stimulant, and patients generally show the effect of this by heightened facial color. A slight dizziness sometimes follows its inhalation, indicating increased capillary pressure. The writer has found that headaches due to night-work are relieved after inhaling the gas for fifteen or twenty minutes. This stimulation joined to the increased richness of the blood in oxyhemaglobine—that is, in its oxygen carrying properties—may account for the many cures reported of troubles due to defective circulation and suboxidation.

On the blood current itself the oxidizing properties of ozone have been observed as distinctly as in the case of other liquids. Specific blood poisons are reported to be eliminated with remarkable rapidity. Scrofulous and even syphilitic toxines are said to be especially amenable to this form of treatment, when they have been found to yield to no sort of drug medication. If this is so, there is no reason why other toxines like that of tetanus, ptomaine poisons, malaria and the virus of rabies, may not be oxidized into innocuous forms, and eliminated from the blood by the usual channels. It is said by de la Coux that ozone "is indicated in the treatment of cancer and other infectious maladies; and many physicians are actively employing ozone in the treatment of these diseases in the medical institutes of France." If this is so, it is unfortunate that reports of their treatment of cancer should not have been published to the world.

The increased action of the heart and the perisaltic movement of the bowels, just spoken of, indicate that ozone inhalations have a direct influence on the nervous system. This is said to be especially marked when neurasthenic patients are submitted to a course of treatment.

The bactericidal action of ozone is so pronounced that it is not surprising to find it especially effective in diseases of microbic

origin. In tuberculosis, catarrh, influenza, grippe, bronchitis, whooping cough, croup and other affections of the respiratory organs due to microbic invasion, the bactericidal properties of ozone are said to act with almost miraculous promptness. And not only does the gas act as a direct microbicide, but it has an indirect bactericidal action as a result of the modifications it is said to produce in the tissues forming the media on which the bacteria lodge and propagate—modifications which render these media unfavorable to the development of the bacteria. This, if true, is a physiological modification of the highest importance in therapeutics; and the claim seems to be based on a reasonable explanation. It is this: ozone modifies the constitution of the blood and of the intra-cavital fluids by rendering them more acid than before; and Dr. Oudin claims that it does this in strong proportions. Now it is well known to biologists that bacteria will only grow in alkaline media. The least acidity kills them. Even a neutral culture of bouillon inhibits the growth of these organisms. Thus ozone not only destroys the bacteria infecting the tissues with which it comes in contact, but it produces in the tissues themselves a physiological condition hostile to other germs which may afterwards find lodgment on them.

Another factor may possibly here come into play. Modern research tends to prove that infectious diseases are not caused directly by the action of bacteria themselves upon the tissues, but by the production of soluble poisons of the nature of alkaloids. This theory has so far advanced beyond the realm of conjecture as to be generally accepted as a final explanation of the symptoms of infectious disease. By ozonization the alkalinity of these toxins is probably neutralized, and so they are rendered inert. That this takes place in laboratory tests has been abundantly demonstrated; and the results reported by physicians of actual experiences seem to indicate that kindred effects take place physiologically. If this should prove to be the case, the therapeutic value of ozone will have a scientific basis of fact that will compel its recognition by pathologists everywhere, and ensure its general adoption in the treatment of all diseases due to the invasion and activity of bacteria.

When we recall the fact that over forty per cent. of deaths are caused by diseases having a microbic origin, and therefore due to infected air, food or water, to which the sterilizing action of

ozone may serve as a preventive; when we recall another long list of diseases having their cause in malnutrition, imperfect circulation and defective nervous conditions, capable of amelioration in ways indicated above, it would seem that ozone presents itself as the most efficient, most readily accessible and easily administered therapeutic agent ever discovered. It is not possible to send all consumptives to the mountains, nor all anemic children to the seaside: but it is possible to create an atmosphere in any home that shall contain all the healing and health-giving properties of mountain air and sea breezes. And if, as it is reasonably claimed, typhoid fever can be practically eliminated from the death list, and the white plague of consumption cured, two of the greatest sources of suffering and sorrow will have been removed from civilized life.

FREIGHT CARS DELIVERED ON STREET RAILROADS.

The possibilities of the electric street railroad for freight purposes are demonstrated in the announcement of the New York Hudson River & Hartford Railroad that Providence merchants and manufacturers whose establishments are not located directly upon the line of steam roads will be given the opportunity to have freight delivered directly to their doors in the cars in which it has been hauled to the city by the steam lines. The company has now acquired the electric street railroad system of the city of Providence and its suburbs. It already controlled all the steam lines radiating from the city. The gauge of the tracks of the two systems is the same. All that will be necessary will be to replace existing rails in the street with those having the deeper grooves necessary to take the wider flanges of the wheels of the rolling stock of the steam lines. Electric locomotives will then haul freight cars from the tracks of the steam lines through the streets to the doors or yards of shippers; and, of course, freight will be collected in the same manner, giving to the manufacturer or merchant as economical conveniences in shipping as those possessed by establishments having spur tracks from the steam railroads. This traffic will be carried on in the night, when the street lines have comparatively little passenger service, and consequently no inconvenience will be caused to the public.

The advantages of such a system of freight delivery and collection are apparent. The merchant will, of course, have to pay some extra charge for delivery, covering transportation over the street lines, and the manufacturer will doubtless have to put in a spur track from the street in order that cars may be delivered into his yard. But against these costs is that of carting goods to and from a freight depot, which, it is stated, is greater than the rates that the railroad will charge for delivery by its street line.—*Iron Age.*

INDUSTRIAL DEVELOPMENT IN INDIA.

The manufacturers and exporters of the United States, when considering the trade of India must not leave out of the calculation the item of home production. If India worked up all its cotton, wool, hair, hides and skins, jute, and metals, and utilized all of the other resources that belong to its rich domain by converting them into manufactured products, there would be little left to be supplied by other countries. Despite the drawbacks that retard the progress of India it makes a fairly creditable showing in manufactures. In 1905 there were 1,336 factories run by steam that were owned by home companies or individuals. The cotton mills (186) are principally in Bombay, the jute mills (40) are in Bengal, near Calcutta, and the rice mills (121) and sawmills (71) for the most part are in Burma. The factories and mills give daily employment to 587,560 persons. Besides the mills operated by steam, water and electric power there has been a revival of the hand looms, and the output from these is double that of the mills. It requires an enormous amount to clothe the millions of people in India, who wear little except cotton the year round. The coolies and poorer classes wear the common muslins, while the higher classes wear the mulmul or high-grade muslins. The mulmuls or high-grades retail at 5 to 13 cents a yard and common muslins from 3 to 4 cents. A suit of clothes for the average poor person of India costs from 15 to 20 cents and the head gear or turban as much more. The females require more goods for a suit, but do not wear the turban.—*Washington Bureau of Manufactures.*

—According to a late official report the area sown to cotton in British India for 1906-7 crop considerably exceeds all records for previous years, and the output, it is estimated, will be unprecedentedly large.

THE PRESSED STEEL CAR COMPANY.

The eighth annual report of the Pressed Steel Car Company, covering the calendar year 1906, shows that the gross sales of the company for the year were $36,158,586.47 and the net profits were $3,381,884.18. President Hoffstot thus refers to the steel passenger car department of the company's works: "The operation of the steel passenger car shop did not contribute to your company's earnings, for the reason that education of men in a new line of industry is expensive and tedious, and full output of work cannot be secured by reason of the unfamiliarity of the workmen with the work; but we have gone far enough into this construction to know that, as a result of the operations to date, we can produce a first-class fire-proof passenger car with only a slight increase in weight over the present wooden type, but at an increased cost. The question as to how great will be the pecuniary benefit to accrue to your company from this department must be left to the future, as the railroads at the present time, when there is an urgent demand for better service and the various State Legislatures are insisting on lower rates, naturally show hesitancy in doing anything that will increase the cost of their equipment."—*Bul. Iron and Steel Asso.*

(*Stated Meeting held Thursday, February* 28, 1907.)

Colloidal Solution: The Intermediate State Between Solution and Suspension.

Robert H. Bradbury.

I. SOLUTION AND SUSPENSION.

When water is poured upon finely divided gold the liquid wets the metal but no further effect is visible. In the absence of external disturbance the gold will remain at the bottom for an unlimited time. This behavior is commonly described by the statement that gold is *insoluble* in water. Modern chemistry has fairly well established the thesis that entire insolubility is an ideal limiting case not actually met with. Compounds like barium sulphate, calcium oxalate and the silver compounds of chlorine, bromine and iodine have solubilities in water which have not only been detected but measured. However, *practical* insolubility is frequent so that the old term is still useful and will be retained.

Now, if the water with the gold lying at the bottom is shaken up, a temporary distribution of the metal through the liquid—a *suspension*—is produced. The only difference is that the particles of gold are very much farther apart on the average than they were before. The liquid is turbid and the gold can be separated from it by a filter. Thus the most superficial inspection shows that there are two things present, a solid and a liquid. In the language of the Phase Rule there are three phases, water, which may have taken up an extremely minute quantity of gold; gold, which may have absorbed a still more minute quantity of water, and vapor, in which only water can be detected, but in which the presence of gold may be assumed for theoretical reasons.

But the Phase Rule, which has been of such supreme service in

the treatment of heterogeneous systems in equilibrium, can give us no help in the present matter, for our suspension cannot be obtained in equilibrium. Left to itself, it instantly begins to separate—sedimentation goes on until each particle of gold has found a resting place. The suspension is dominated absolutely by gravitation. Other forms of energy play no role. The free energy which it contains is the same as that of a raised weight and can be calculated by multiplying the weight of the gold by the average fall, which would be approximately half the depth of the water.

When water is poured over copper sulphate the system conducts itself in an entirely different way. The blue color of the solid appears, first in the contiguous liquid and later in the remote. If the quantity of the sulphate is not too large, it disappears entirely; if it is in excess the liquid takes up a quantity which is always the same at the same temperature and pressure and which increases rapidly with the former and slowly with the latter. When equilibrium is reached, the distribution of the sulphate through the liquid is entirely uniform. The differences of concentration which arise during the dissolving are adjusted spontaneously by diffusion, without the intervention of any external agency. This final condition is absolutely permanent. Nothing analogous to sedimentation occurs, no matter how long a time is allowed, and so far as we know gravitation has no power whatever over the dissolved sulphate, for all attempts to establish a greater concentration in the lower portions when a long tube is filled with a solution and placed vertically, fail.

Just as the solution is the natural permanent state of the two substances—water and copper sulphate—when in contact, so the dissolving of the sulphate in the water is a self-acting, spontaneous process, which occurs without external energy being added to the system. On the contrary it reduces the free energy of the system and therefore can be made to do external work. In this work, which the dissolving process can be made to do, the driving force is the *osmotic pressure* of the copper sulphate. The sulphate tends, as we have seen, to distribute itself evenly through the liquid—it behaves like a gas which when liberated in an empty space proceeds to occupy evenly every portion of the space.

If a partition is interposed which is saturated throughout with the water but will not permit the sulphate to pass, the latter, in

its effort to expand into the rest of the liquid, will exert osmotic pressure upon the partition and if it is adjusted to move against an external resistance, work will be done. The sulphate can be placed in the bottom of a vertical cylinder filled with water and a piston which allows the water, but not the sulphate to pass, inserted. Then as the sulphate dissolves and endeavors to expand into the water above the piston, it will exert a pressure and, if the latter be weighted, the weight will be raised and work will be done.

Conversely, if, after the copper sulphate has occupied the entire liquid, the piston is burdened with a weight which is kept in excess of the osmotic pressure it will be forced downward, the sulphate will be crowded into a smaller and smaller volume of liquid and will finally crystallize.

Thus by means of a "semi-permeable" membrane it can be shown that the dissolving of a solid can be made to do work and that when the same amount of work is done upon the system the dissolved substance is again separated from the solvent.

2. THE EFFECT OF DECREASING THE SIZE OF THE PARTICLES.

It is always easy to formulate distinctions which apply to the typical members of two different classes—it is the transitional intermediate ones that are difficult to classify. For instance, one would hardly expect any difficulty to arise in deciding whether to call a given system a solution or a suspension. The distinctions seem unmistakable—

Solution.	Suspension.
1 Homogeneous.	1 Heterogeneous.
2 Clear.	2 Turbid.
3 Permanent.	3 Temporary.
4 Formed by a spontaneous process or contact.	4 Formed by external action.
5 Non-separable by filtration or decantation.	5 Separable by these means.
6 Formation liberates energy and can produce work.	6 Formation absorbs energy.

Starting with matter in a state of coarse mechanical suspension in water let us imagine the size of the particles gradually to decrease. We shall find that the above criteria fail us and that it becomes almost impossible to decide whether we are to call the system a solution or a suspension.

By powdering in a mortar or similar mechanical means sub-

stances can be pulverized until the average diameter of the grain is ¼ of a micron.* Any substance, unless it happened to have the same refractive index as water, would produce a strong turbidity easily visible to the naked eye if the particles were as large as this. But we may anticipate that when the particles became very much smaller than the wave-length of light they might cease to reflect in such a way as to show their presence to the unaided vision. Now the wave-lengths of the visible frequencies of light are grouped between 1 micron and 0.1 micron. Therefore we might predict that somewhere about the diameter of 0.1 micron the particle would no longer render the liquid turbid to the unaided eye. This prediction is in full accord with experiment. Measurements of the size of the particles are difficult and few, but in the case of gold the limiting size of the particle-producing turbidity is about 0.1 micron—probably less. From the high density of gold and its behavior toward light we should expect it to produce turbidity with a smaller particle than other substances. So far as I am aware, exact measurements of the size of the particles in colloidal solutions of oxides, hydroxides, sulphides and organic colloids have not been made, but it is a safe statement that a much larger particle than 0.1 micron is required to make the solution turbid. Work is going on actively in this field and we may expect definite results in the near future.

Are we to call this clear liquid containing finely divided metallic gold a solution or a suspension? The most natural reply is that there has been no change in principle—the delicacy of the eye has failed us, that is all. Since the liquid still contains particles of gold distributed through water, it is a suspension.

It is true that the microscope will enable us to detect particles decidedly smaller than 0.1 micron floating in a liquid, but there is a far more powerful instrument for this purpose. Everyone has noticed that when a beam of light enters a dark room through a chink in the shutter the floating motes of the air spring into plain visibility. Tyndall was the first to call attention to the possibilities of the light-beam in detecting suspended matter. That the effect is really due to motes and not to the air itself can be demonstrated by a familiar lecture experiment. The inside of a glass box is smeared with glycerine and it is allowed to stand

*A micron is .001 millimeter.

over night. The solid matter settles and then when the beam is sent through there is no trace of its passage—the box is "optically empty." The purest distilled water contains countless floating particles and it is difficult to eliminate them, so difficult that until recently it was an open question whether the water molecules themselves did not disperse the light, but Spring has shown that if a little zinc hydroxide is precipitated in it the suspended matter is all carried down and the water becomes optically empty.

Now if we focus an image of a powerful arc, or better, of the sun, in the liquid and examine it under the microscope, making provision for the prevention of any accidental light reaching the eye, we have the *ultra-microscope* of Siedentopf and Zsigmondy. This is an instrument of wonderful power in the investigation of the infinitesimal, and to it the recent great advance of our knowledge in this direction is largely due. With it particles as small as 5 millimicrons* can be *separately seen* and particles much smaller—how much smaller no one knows—can be detected by the visibility of the cone of light. By means of it all gold solutions down to and somewhat beyond 5 millimicrons can be shown to contain their gold in the solid form. This brings us in the midst of the domain of the infinitely little. The smallest particle which can be seen separately is only about $\frac{1}{100}$ of the dimensions of the smallest visible light wave and only 50 times the diameter assigned by van der Waals, Exner and others to the molecule of hydrogen (0.1 millimicron). The smaller particles which cannot be seen separately, but still reflect the light and polarize it, cannot contain more than a few molecules, but they must contain more than one, for there are other gold solutions still more finely divided which give no light cone at all—are optically empty—and yet are identical in their other properties.

Liquids containing solids in this condition of excessive subdivision have received the name of *colloidal solutions.* The facts just discussed have led some chemists† to regard them simply as suspensions of great fineness. But the matter is not so simple as this and before settling it in this off-hand way we ought to inquire how true solutions behave toward the cone of light.

*A millicron is .001 micron = .000001 millimeter.

†Stöckl & Vanino. Zeitschr. Pysikal. Chem. 30, p. 98 (1899).

Spring† and Lobry de Bruyn‡ have done some interesting work upon this point which has not attracted as much attention as it deserves. The results briefly are as follows: Solutions of salts of K, Na, Ca, Sr, Ba, Zn, Mn, Co, Ni, Cd are optically empty, but water solutions of chlorides, nitrates or sulphates of Al, Cr, $Fe^{III}Cu$ and Pb show the passage of the beam strongly. Spring has attributed this to hydrolysis producing a colloidal solution of the hydroxide and his explanation is supported by the facts that the solutions in question redden litmus and that hydrochloric acid weakens the cone and, in sufficient quantity, causes it to disappear. However, true solutions of high molecular weight, for instance, ordinary sugar, raffinose, phosphomolybdic acid and the benzoyl esters of mannite and dulcite, show the effect strongly.

Starting with the molecular theory, it is clear that the homogeneity of any solution is only apparent and detecting solid matter in it is a question of delicacy of method. Van Calcar and Lobry de Bruyn placed solutions—e. g. of KI, KCNS, Na_2SO_4—in a centrifugal machine making 2400 turns per minute. The experiment was arranged so that at the end of the centrifugation the liquid was contained in four different compartments. The dissolved substance was contained chiefly in the solution from the outer compartment. From a 9% solution of Na_2SO_4 about one-third crystallized in the outer compartment.

It seems, therefore, that using the utmost refinement of experimental method we can prove that colloidal solutions are heterogeneous and therefore turbid, but it also appears that if we called them mere suspensions on this account we should have to treat most true solutions in the same way—the conception solution would disappear from science.

We may also note the fact that a colloidal solution is permanent so long as the fineness of subdivision persists. Sedimentation takes place in many cases, but it is always preceded by the union of many of the smaller particles to larger ones—a kind of coagulation. There are various ways of preventing this, and so long as it is prevented, the distribution remains uniform. Gravitation does not determine the sequence of events. It has retired

†Bulletin Acad. Royale Belg., 1899, p. 300.

‡Rec. Travaux Chimiques des Pays Bas, 23, p. 155 (1904).

into the background, as we shall see later, in favor of kinetic energy, surface energy and electrical phenomena. It follows, of course, that the solid cannot be separated from the liquid by decantation. Ordinary filtration is completely without effect.

We have now seen the justification for collecting these substances in a class by themselves. Naturally it is not easy to define the exact boundaries which separate them from true solutions on the one side and suspensions on the other. Probably there is no exact line of separation, the classes merging into each other. We shall take up this point later.

3. THE COLLOIDAL SOLUTION OF GOLD.

Preparation. The first necessity is doubly-distilled water of special purity. For the second distillation a silver condenser must be used. Access of air or contact with a ground glass stopper will charge it with solid particles and make it useless. It is kept in bottles stoppered with corks wrapped in tinfoil. When the electric arc is allowed to burn between two gold wires under this water the metal is obtained in very fine division on account of the sudden cooling of the vapor, and a colloidal solution is produced. This method is due to Bredig and it applies also to Pt, Pd, Ag and many other metals.*

The other general method is by the reduction of an extremely dilute solution of gold chloride with formaldehyde at a boiling temperature or with an etherial solution of phosphorus in the cold. If the experiment succeeds the liquid is bright red and entirely clear. In some cases the gold particles are so small that even the ultra-microscope fails to detect them. Sedimentation does not occur so long as coagulation is prevented. Under favorable circumstances if the water used was pure and freezing is not allowed, the solutions are practically permanent. In those prepared by the arc the subdivision is not so fine. They are purple-red or violet, and somewhat less stable.

The favorable effect of great dilution of the $AuCl_3$ in chemical reduction is easily understood. In a strong solution the minute particles first formed find abundant dissolved gold in the liquid and grow at the expense of it until glittering flakes of gold

*Colloidal solutions of K, Na, Li, Rb and Cs in anhydrous ether have been made by a similar method.

are produced and sedimentation occurs. But when the quantity of gold in each c.c. is very small the production of the first submicroscopic particle exhausts it and growth is impossible.

Properties. As already stated, the subdivision is so extreme in some solutions that the light cone is scarcely visible in the ultra-microscope. Particles slightly larger produce a cone which cannot be separated into individuals. That these liquids really contain colloidal gold and not some red compound of the metal can be proved by adding a solution of almost any soluble acid, base or salt—any electrolyte—when the color of the liquid changes to blue and the particles in the cone at once become visible. From about 5 millimicrons upward the particles are separately visible. They are brightly colored—green, red or yellow. Some solutions contain only green particles, some only red, some only yellow and in still others all three are present. Naturally, the color of the liquid by transmitted light is complementary to that of the particles it contains. The red solutions contain chiefly green particles, the violet yellow ones. It is impossible to predict the size of a particle from the color. All three occur in widely different dimensions, but on the whole the green are the finest and the yellow the coarsest.

The particles are in continual motion, the smaller ones moving most rapidly. Zsigmondy* compares the appearance of the light-cone to a swarm of gnats in the sunlight. The motion of the smallest particles can be resolved into two components. There is a direct progression in which the particle covers from 1,000 to 10,000 times its own length in a second and an oscillation of very short period. The progressive movement is zig-zag and variable, so that a particle after describing a zig-zag, each line of which is 100 to 1,000 times its own diameter and taking perhaps $\frac{1}{8}$ of a second for each, will rush quite off the field of view in a straight line. This motion shows no decrease with time. Solutions more than a year old exhibit it just as actively as at first, unless coagulation has begun.

It is natural to expect some connection between the heat and light which are projected into the liquid and the motion of the particles. On this point Zsigmondy calls attention to the facts:

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*Zur Erkenntnis der Kolloide, p. 107. This book is an excellent monograph on the colloidal gold solutions.

1. That when a water chamber is interposed the motion is unaffected. 2. That there is no relation between the direction of motion and the direction of light. 3. That the motion is independent of the length of time the beam has acted. When the beam is suddenly shifted to a new part of the liquid which has been in darkness the motion is found to be quite as active. 4. That the motion is independent of the intensity of the light, being just as active in the wider parts of the cone as at the focus and just as active when electric light is employed as by sunlight.

The cause of this most interesting phenomenon is obscure. It may be electrical in nature—all the particles are negatively charged. But it must be recalled that these masses can contain only a few molecules. The fact that the motion greatly increases with decreasing size of the particle may indicate that we are here observing the kinetic energy of the molecule which we call heat.

The method by which the size of the particles is ascertained is interesting. Of course direct measurement is absolutely out of the question. The quantity of gold in each c.c. of the liquid is known from the weight of gold chloride used in making it. Dividing this by the density of gold which may be taken as 20 we obtain the volume of the gold in the unit of volume of the liquid. The ultra-microscope has an attachment—an ocular micrometer—by means of which the volume of the illuminated portion of the liquid can be determined. Thus the total volume of gold in the light cone becomes known. If the liquid is so diluted that the number of particles is not too great, they can be counted and by division the volume of each particle is obtained. The cube root of this gives the diameter on the assumption that the particle is a cube. Putting this into a formula we have

$$D = \sqrt[3]{\frac{M}{20\ N}}$$

where D is the diameter sought

M the weight of gold in the light cone

N the number of particles.

There is no reason to think that the particles are cubical, but some shape must be assumed and the effect on the result would be small. It is clear that the figure obtained is an average simply. The error does not exceed 20%.

When a solution of any electrolyte—common salt answers

well—is added to a red colloidal gold solution, the color changes to blue and the gold collects in larger particles. Thus a bright-red solution so finely divided as scarcely to show the track of the beam was placed in the ultra-microscope and sodium nitrate solution added.* The light-cone became visible, moving spherical yellow cloudy masses appeared in the liquid. The clouds condensed to numberless minute particles in violent motion. These particles in turn coalesced to larger ones which moved, but more slowly than before.

Where the gold solution is pure this change is irreversible—the gold once coagulated cannot be restored to solution except by converting it into gold chloride and repeating the reduction. All colloidal metals and most oxides and sulphides act in the same way and are called *irreversible* colloids. On the other hand, dextrim, gum arabic, gelatine and most kinds of albumin when separated from water can again be dissolved in it and the separation and re-solution repeated an unlimited number of times. Such substances are called *reversible* colloids. It is an interesting fact that in presence of a reversible colloid, like gelatine, the coagulation of gold becomes reversible. Thus, if gelatine is added to a colloidal gold solution and the mixture allowed to evaporate on a glass plate, it coagulates to a blue or violet mass. This is composed of larger units, but the gold particles have not coalesced. Compound particles containing from a hundred to a thousand gold particles imbedded in gelatine have been formed. They seem to contain equal volumes of gold and gelatine and of course are very much richer in gold by weight. When heated with water the gold particles are again disseminated and the colloidal solution is reproduced. The addition of a small quantity of gelatine or some other reversible colloid to a gold solution will entirely prevent the coagulation by electrolytes and the consequent change in color from red to blue. Different colloids exhibit great differences in the quantity required to produce this protective action. Thus gelatine is, weight for weight, about 20 times as effective as egg-albumin and about 100 times as efficient as gum arabic.

4. We may now return for a moment to the distinction between colloidal solutions and true solutions on the one side and

*Zsigmondy, p. 115.

true suspensions on the other. This is a most interesting and important question, but investigation has not gone far enough to return a complete answer to it.

The greatest difference between true crystalloidal solutions and colloidal solutions is the lack of the osmotic energy of volume which practically determines the behavior of the latter. Hence a colloid exerts little or no osmotic pressure and no external work is afforded by the process of dissolving it. For the same reason the freezing and boiling points are sensibly identical with those of the pure solvent. Another aspect of the same fact is that the force which holds solvent and colloid together is far weaker than in the case of an ordinary solution. Their separation is easier.

Another important difference is the behavior toward the electric current. A crystalloidal solution is either a non-conductor—like sugar—or else it is dissociated into ions which transport equivalent amounts of electricity to both poles. But a colloid all migrates either to one pole or the other—usually to the anode—although some, like the hydroxides of iron, aluminum, chromium, thorium, zinconium and cerium pass to the cathode. Accordingly the particles in most colloidal solutions must be negatively charged and this is in agreement with experiments which show that when two substances are brought into contact the one with the highest dielectric constant is charged positively and the other negatively. Owing to the very high dielectric constant of water (80) most substances would be charged negatively on contact with it.

Lack of optical homogeneity is another distinction, but we have seen that many true solutions show the same phenomenon.

There is nothing in crystalloidal solutions corresponding to the *coagulation* of colloids. This distinction holds good whether we consider the turning of the red gold solutions to blue with simultaneous coalescence of the particles or the setting of other colloids to a jelly, as in the case of gelatin, alumina and silicic acid.

When a solution of a positively charged colloid like stannic acid is mixed with one in which the particles have a negative charge, like gold, then, if the proportions are correct, electrical neutralization occurs and both precipitate in an extremely intimate mixture. In this particular case the precipitate is "purple

of Cassius," which is mixed colloid of stannic acid and gold.

Among the distinctions between colloidal solutions and suspensions we have in the first place the immensely fine division of the solid.*

Then the settling of a suspension is a reversible process. One can always shake it up and distribute the solid again in the liquid. The irreversible coagulation of some colloids and the setting of some to jellies are without good analogies among the suspensions, though these are suggestive phenomena in the coalescence of fine particles in suspension which sometimes precedes settling.

The coagulation of a colloid may liberate considerable quantities of energy. Thus when a gram atom of colloidal silver coagulates something like 27,000 cal. are set free, and when the precipitated jelly turns to ordinary silver there is a further liberation of about 6,500 cal. This is a most important distinction between colloidal solutions and suspensions and is of itself a complete justification for making them a separate class, for the trifling amount of gravitational energy which is set free in the settling of a suspension could not be measured in any colorimeter.

5. GENERALITIES.

In the main, the chemist in the enormous development of his science during the 19th century proceeded from crystal to crystal. The analytical chemist has been forced—much to his discomfort—to occupy himself somewhat with colloidal matter—for instance, in the case of silica and some sulphides—while the organic chemist has started with materials purified by re-crystallization, has purified his products in the same way and has thrown everything which could not be induced to crystallize under the head of tarry side products, "Schmieren." The chemist has devoted himself essentially to the crystalloids and this was a necessary specialization. The vast advance which has been made is an effective answer to anyone who would criticize the point of view. But as we have seen, the problem of colloidal matter has now been attacked and much more than a beginning has been made. The new science is not only born but is in sound, vigorous and wonderfully rapid growth. In it the simple and

*Zsigmondy. Zur Erkenntnis der Kolloide, p. 11.

beautiful laws which have guided so surely the development of the classical chemistry must be set aside. Possibly the stochiometric laws themselves are merely the result of the limitations upon possibility which are set up by the enforcement of a definite arrangement of the molecules in the crystal. This bold suggestion is due to Lottermoser. An obvious objection is that the stochiometric laws apply to liquids and gases in which there is no definite molecular arrangement. But they certainly do not apply to colloidal compounds. If I have a salt solution and am certain that it contains no other compound of sodium or of chlorine I can determine the chlorine and calculate the sodium with the utmost exactness. The analogous calculation is impossible with a colloidal compound. In a sample of purple of Cassius both the gold and the stannic acid must be determined, for their percentage may vary within wide limits and with the variation occurs a continuous alteration in properties. Much interesting work has been done by Sabanajeff and others upon the molecular weights of dissolved colloids. The figures obtained are enormous—50,000 for silicic acid. But it is doubtful how much reliance to place upon them, for the fundamental assumption that the van't Hoff-Raoult laws apply to colloidal solutions is extremely questionable. It is very uncertain that the slight observed depressions of the freezing point were really due to the dissolved colloid. When "silicic acid" is made from sodium silicate and hydrochloric acid the jelly obstinately retains sodium chloride Even when washed with hot water until most of the jelly has dissolved and the chlorine reaction has long been absent in the washings, appreciable quantities of salt are still present. This obstinate retention of traces of other substances is an undesirable colloid characteristic which has long been familiar to the analyst. Thus the trifling observed depressions and indications of osmotic pressure may be accounted for and the basis for the calculation of the molecular weight disappears.

This same fact, the formation of a compound undecomposable by water, accounts for the astounding poisonous action of infinitestimal quantities of silver, mercury and notably copper on plant cells. The albumin absorbs the copper, forming an irreversible colloidal compound, and so it happens that copper in a dilution of 1 : 1,000,000,000 will damage and finally kill organ-

isms upon which HCN 1 : 1000 (a million times as concentrated) has no appreciable effect.

I have already trespassed far too long upon your attention. It would be interesting to discuss in detail the applications, both scientific and industrial, of our subject, but this alone would furnish material for many lectures. Physiology is concerned chiefly with colloids. Enzymes are in colloidal solution, and their peculiar activity is the result of the enormous surface exposed owing to the fine division. In the dyeing industry the fibres are typical colloids and many of the dye-stuffs are in colloidal solution. In photography the gelatin and albumin of plates, films and paper are colloids and the silver haloids are at first in colloidal solution and separate in crystalloidal state during the ripening. The modern industry of high explosives works with colloidal matter. Colloidal metals are employed in the preparation of filaments for the incandescent lamp. The decomposable matters of sewage are mainly in colloidal solution, negatively charged like most colloids and the use of iron compounds in coagulation is an instance of the electrical neutralization and mutual precipitation of two oppositely charged colloids, the positive colloid being ferric hydroxide. The colloids now have a journal devoted entirely to their interests. It is not extravagant to express the hope that the expansion of this subject may in time produce an organized body of knowledge which will equal in scientific interest and practical importance the chemistry of crystalline matter.

Book Notices.

PUBLICATIONS RECEIVED.

The Submarine *versus* the Submersible, by Simon Lake. 13 pages, plates, 8vo. Reprinted from Journal of the American Society of Naval Engineers. May, 1906.

Report of the Commission of Education for the year ending June 30, 1904, volumes i and ii. 2480 pages. Washington. Government Printing Office, 1906.

The Transit, 1906. Published annually by the Engineering Society of the University of Iowa. 64 pages, illustrations, plates, portraits, 8vo. Iowa City, Iowa.

Pennsylvania State Department of Agriculture. The Monthly Bulletin

of the Division of Zoology, vol. iv, No 2. June, 1906. Harrisburg. State Printer, 1906.

Pennsylvania State College Agricultural Experiment Station. Bulletin No. 78. A test of commercial cultures for legumes. 13 pages, 8vo. State College, July, 1906.

Report of Tests Upon Sand-Lime Bricks. By Ira H. Woolson, E.M. Reprint from "Proceedings of the Second Annual Convention of the National Association of Manufacturers of Sand-Lime Products," held in Detroit, Mich., December 5, 6 and 7, 1905. 35 pages, illustrations, plates, 8vo.

University of Cincinnati. Illustrated booklet. Unpaged, illustrations, 24mo. Cincinnati, 1906.

Asbestos Protected Metal Company. Booklet describing asbestos protected metal. 23 pages, 12mo. Canton, Mass., 1906.

Universal System of Machine Moulding. Ph. Bonvillain & E. Ronceray, Paris-Aubervilliers, patentees and makers. 35 pages, illustrations, 8vo.

United States War Department, Annual Reports for the fiscal year ended June 30, 1905. Vols. 10, 11, 12, 13 and 14. Washington. Government Printing Office, 1905. 5 volumes, illustrations, plates, 8vo.

Chicago Pneumatic Tool Company. Catalogue No 20. Franklin Air Compressors, pneumatic tools and appliances. 116 pages, illustrations, 8vo. Chicago, 1906.

List of books on Steam and Gas Engines, published by the Brooklyn Public Library. 23 pages, 16mo. Brooklyn, 1906.

Was sind und wie enstehen Erfindungen? Eine entwickelungstheroretische Studie von Ingenieur Josef Löwy, Mitglied des K. K. Patentamtes in Wien. 18 pages, 8vo. Wien, A Hartleben, 1907.

U. S. Geological Survey. Mineral products of the United States, calendar years 1896 to 1905. Folded sheet. Washington. Government, 1906.

Cornell University. The President's Report 1905-1906. 50 pages, 12mo. Ithaca, N. Y., University, 1906.

Providence, R. I. Annual Report of the City Engineer for the year 1905. 80 pages, illustrations, 8vo. Providence. City printers, 1906.

Rivetage par M. Fricker. 168 pages, illustrations, 12mo., Paris, Gauthier-Villars, n. d.

The above volumes are the latest additions to the well-known series Encyclopédie Scientifique des Aide—Mémoire issued under the editorial direction of M. Léauté. The books are uniform with previous issues and form valuable monographs on the subjects to which they relate. They cover a wide field and are written by specialists in the various branches. The price is two francs, 50c. in paper, and three francs in cloth. R.

Sections.

ELECTRICAL SECTION.—*Stated meeting*, held Thursday, February 21st, at 8 P.M. President Thomas Spencer in the chair.

Dr. Lee de Forest presented a paper on "The Development of Wireless Telegraphy," which was fully discussed by the members present. A vote of thanks was passed to the speaker and the meeting adjourned.

RICHARD L. BINDER, *Sec'y.*

Stated meeting, held Thursday, April 11th, at 8 P.M. President Spencer in the chair. Present, seventy-eight members.

Dr. Henry Leffmann presented a paper on "Electrical Methods Direct and Indirect for the Purification of Water," which was fully illustrated by specimens and slides. The paper was discussed by Drs. Goldsmith, Wahl, Williams and Messrs. Colvin, Hering, Spencer, Cameron and others. A vote of thanks was passed to the speaker of the evening and the meeting adjourned.

WM. H. WAHL, *Sec'y pro tem.*

MINING AND METALLURGICAL SECTION.—*Stated meeting*, held Thursday, January 17th, at 8 P.M. Dr. Wahl in the chair. Present, thirty-eight members.

Prof. Angelo Heilprin presented a paper, fully illustrated, on "The Interrelation Between Earthquake and Volcanic Phenomena." The thanks of the meeting were voted to the speaker and the meeting adjourned.

WM. H. WAHL, *Sec'y pro tem.*

Stated meeting, held Thursday, January 31st, at 8 P.M. Mr. Clamer in the chair. Present, fifteen members.

Dr. William Campbell presented a paper on "The Microscopic Examination of Certain Sulphides." The thanks of the meeting were voted to the speaker and the meeting adjourned.

WM. H. WAHL, *Sec'y pro tem.*

SECTION OF PHYSICS AND CHEMISTRY.—*Stated meeting*, held Thursday, January 17th, at 8 P.M. Dr. Wahl in the chair. Present, thirty-eight members.

Prof. Heilprin presented a paper on "The Interrelation of Earthquake and Volcanic Phenomena," which was fully illustrated. A vote of thanks was passed to the speaker and the meeting adjourned.

WM. H. WAHL, *Sec'y pro tem.*

Stated meeting, held Thursday, February 28th, at 8 P.M. Dr. H. F. Keller in the chair. Present, twenty-five members.

Dr. R. H. Bradbury presented a paper on "Collodial Solution, the Intermediate state between Solution and Suspension." The paper was discussed by Drs. Keller and Williams and Messrs. Hering and Spencer. The thanks of the meeting were voted to the speaker of the evening and the meeting adjourned.

EDWARD A. PARTRIDGE, *Sec'y.*

Stated meeting, held Thursday, March 28th, at 8 P.M. Dr. Bradbury in the chair. Present, fifteen members.

Dr. J. Merritt Matthews presented a paper on "The Theory of the Dyeing Process," which was discussed by Drs. Goldsmith, Williams, Bradbury and Mr. Colvin. The thanks of the meeting were voted to the speaker and his paper recommended for publication in the *Journal*. Adjourned.

W. J. WILLIAMS, *Sec'y pro tem.*

MECHANICAL AND ENGINEERING SECTION.—*Stated meeting*, held Thursday, January 17th, at 8 P.M. Dr. Wahl in the chair. Present, nineteen members.

Prof. Angelo Heilprin read the paper of the evening on "The Interrelation of Volcanic and Earthquake Phenomena," which was fully illustrated. The thanks of the meeting were tendered to the speaker and the meeting adjourned.

WM. H. WAHL, *Sec'y pro tem.*

Stated meeting held Thursday, February 7th, at 8 P.M. President Charles Day in the chair.

The paper of the evening was by Mr. J. C. Irwin, of New York, on "Signal System on the New York Central and Hudson River Railway." In the absence of the author it was read by Mr. Day. The paper was illustrated, and was discussed by the members, and was referred for publication. Adjourned.

FRANCIS HEAD, *Sec'y.*

Stated meeting, held Thursday, March 7th, at 8 P.M. Prof. Lewis M. Haupt in the chair. Present, forty members and visitors.

The paper of the evening was read by Mr. Paul T. Warner on "The Modern Locomotive," which was fully illustrated and discussed by Messrs. Colvin, Haupt and Johnson.

After a vote of thanks to the speaker the meeting adjourned.

FRANCIS HEAD, *Sec'y.*

SECTION OF PHOTOGRAPHY AND MICROSCOPY.—*Stated meeting*, held Thursday, January 17th, at 8 P.M. Dr. Wahl in the chair. Present, thirty-eight members.

Prof. Heilprin presented a paper on "The Interrelation of Earthquake and Volcanic Phenomena," which was fully illustrated. A vote of thanks was passed to the speaker and the meeting adjourned.

WM. H. WAHL, *Sec'y pro tem.*

Stated meeting, held Thursday, April 4th, at 8 P.M. Prof. Lewis M. Haupt in the chair. Present, thirty-five members and visitors.

Dr. Edward Goldsmith gave an informal talk on "Observations on a Recent Trip to the Windward Islands." The subject was illustrated by lantern slides. At the conclusion of the speaker's remarks the subject was discussed by some of the members. A vote of thanks was tendered to the speaker of the evening and the meeting adjourned.

LOUIS E. LEVY, *Sec'y pro tem.*

The Franklin Institute.

(Proceedings of the stated meeting held Wednesday, February 20, 1907.)

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, February 20, 1907.

PRESIDENT WALTON CLARK in the chair.

Present, thirty-two members and visitors.

Additions to membership since last report, ten.

The President introduced Dr. Chas. F. Himes, who presented a communication on "The Preservation of Written Historical Documents," and illustrated his remarks by showing a document reinforced with silk gauze, where its fold had worn through by reason of much handling, and explained a method of successfully applying the reinforcing materials.

Mr. W. C. L. Eglin, of Philadelphia, addressed the meeting on "High Efficiency Incandescent Lamps." The lecture hall being brilliantly lighted for the occasion by replacing the usual incandescent lamps with those of the variety known as the "Tantalum" lamp. An interesting discussion followed, which was participated in by Messrs. Hammer, Eglin, Heany, Clark and Dr. Meeker.

Mr. R. A. Smith, of Philadelphia, brought to the attention of the meeting a new chemical compound, "Oxodium," and, assisted by Mr. C. C. Balderston, gave a demonstration of generators used for producing pure oxygen gas from Oxodium, and described the various uses of the compound in submarine boats, tunnels, mines, etc. The subject was discussed by Drs. Himes, Williams, Meeker and Messrs. Hammer, Balderston, Stratton and others.

The President expressed the thanks of the meeting to the speakers of the evening. Adjourned.

H. L. HEYL, *Sec'y pro tem.*

(Proceedings of the stated meeting held Wednesday, March 20, 1907.)

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, March 20, 1907.

PRESIDENT WALTON CLARK in the chair.

Present, eighteen members.

Additions to membership since last report, ten.

The President announced the appointment of the standing committees of the Institute for the year 1907.

The President then introduced Mr. James Howard Bridge as the speaker of the evening, who presented a communication on "Ozone: Its Nature, Production and Uses." The speaker illustrated his remarks by the exhibition of an ozone producing apparatus of special design and construction. On motion, the subject was referred to the Committee on Science and the Arts for investigation and report.

Mr. H. Clyde Snook, of the Roentgen Mfg. Co., gave an interesting

talk, illustrated by lantern slides, showing diagrams of the variations in vibrations in the production of the Roentgen Rays under varying conditions.

A vote of thanks was passed to the speakers of the evening. Adjourned.

H. L. HEYL, *Sec'y pro tem.*

(Proceedings of the stated meeting held Wednesday, April 17, 1907.)

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, Pa., April 17, 1907.

PRESIDENT WALTON CLARK in the chair.

Present, eighty-two members and visitors.

The report of the Board of Managers showed an addition of five persons to the membership since last report.

President Clark made an announcement of the fact that the Board of Directors of City Trusts had voted to appropriate the Franklin Fund to the Franklin Institute for the purpose of erecting a new building as a memorial to Benjamin Franklin. The President stated that further details of this subject would be presented at a later meeting.

The President thereupon stated that Messrs. Dodge and Day had made arrangements to have Prof. V. Karapetoff, of Cornell University, deliver an address on "The Human Side of the Engineering Profession" before a gathering composed of their engineers in conjunction with the regular meeting of the Franklin Institute in order that Prof. Karapetoff's address may be delivered before this meeting. The President thereupon vacated the chair to give place to Mr. Conrad A. Lauer, representing the Engineers' and Constructors' Society, who then introduced Prof. Karapetoff as the speaker of the evening.

At the close of the lecture the subject was thrown open for discussion, in which Messrs. James M. Dodge, H. F. J. Porter and President Walton Clark participated.

On motion of Mr. Chas. Day, seconded by Mr. Kern Dodge, the thanks of the meeting were unanimously voted to the lecturer and the meeting was adjourned.

WM. H. WAHL, *Secretary.*

THE BOARD OF MANAGERS.

(Extract from the minutes of the Board meeting, held Wednesday, February 13, 1907, relative to the retirement of Mr. John Birkinbine as President.)

At the stated meeting of the Board of Managers held February 13th, 1907, the following minute upon the retirement of Mr. John Birkinbine from the presidency of the Institute was adopted:

"WHEREAS, The services of Mr. Birkinbine as Chairman of this Board has been terminated by his retirement from the office of President of the Institute, be it

"*Resolved*, That his colleagues of the Board of Managers, fully cognizant of the unremitting efforts devoted to the interests of the Institute by Mr. Birkinbine throughout the ten consecutive years of his varied serv-

ices as its President and as Chairman of the Board, hereby record their appreciative recognition of the great value of those services in the promotion of the Institute's activities; and be it further

"*Resolved*, That this minute be published in the *Journal* of the Franklin Institute and an engrossed copy thereof transmitted to Mr. Birkinbine."

Attest: H. L. HEYL, *Actuary*.

Annual Reports of the Schools of Drawing, Machine Design and Naval Architecture for the Sessions of 1906-1907.

THE DRAWING SCHOOL.—This school has had a very satisfactory season in the work that has been done and the progress that has been made, although the number of students was somewhat less than last year. What is taught here forms the best possible introduction to all mechanical pursuits, and should be taken advantage of by everyone whose tastes lie in that direction, or who is already at work making things. Things cannot be made without being planned, either by the maker or by someone else, and the only successful and economical way of planning is to put the conception upon paper in such manner that the shape and size of all the details harmonize with the intended purpose. Without this, modern civilization would be impossible. Hence the great importance to everyone connected with mechanical production and advancement, of the knowledge of the principles and a fair amount of skill in connection with graphic analysis and mechanical drawing. Cut-and-try methods are passed. Modern system and organization require that inventions, structures, and designs be worked out fully on the drawing board before any material is used or work employed. Besides, the gathering of the material and the work upon it are governed by the drawing, so that a good knowledge of drawing is essential to any one who would take a responsible position in connection with it. The study is not intended alone for those who wish to become draughtsmen, but is important to all those who hope to be of much account in any of the practical departments.

THE FOLLOWING STUDENTS HAVE DESERVED HONORABLE MENTION:

In the Senior Mechanical Class.

Louise Fithian,
Walter Saatman,
William Undercoffer,
Herman Karsch,
Howard G. Balz,
Charles W. King,
Alvin Hatfield,
Frank Regnault,

James F. Fennell.

In the Intermediate Class.

George F. Johnson, Jr., Arthur V. Conover,
Craig Annê, Ralph Barnum,
Amos E. Temple, Eugene Heckel,
Theodore Richter, David H. Trego,
Edward F. Parsons, Otto Schaaf,
Howard Reeder.

In the Junior Mechanical Class.

Stanley K. Weber.

In the Architectural Class.

William A. Markert, Richard D. Tifft,
John M. Cromwell, Jr., George M. Croll.

In the Free Hand Class.

David Bowers, John J. Draffan.
Carl Ulrich.

THE FOLLOWING STUDENTS ARE AWARDED SCHOLARSHIPS FROM THE B. H. BARTOL FUND:

Eugene Heckel, Arthur V. Conover,
George F. Johnson, Jr., William A. Markert,
Richard D. Tift.

THE FOLLOWING STUDENTS, HAVING ATTENDED A FULL COURSE OF FOUR TERMS, WITH SATISFACTORY RESULTS, ARE AWARDED CERTIFICATES:

Walter Saatman, William Undercoffer,
James F. Fennell, Clifford V. Raffo,
Charles W. King, Henry Schwemmer,
James S. Cassel, Louis C. Haug,
Clarence G. Stallman, Frank Butler,
Joseph M. Schneider, Thomas McLoughry,
Howard G. Balz, Joseph O'Keefe,
Henry Hagstrom, John A. Schaffer,
Clayton H. Robson, Hilton Le Roy,
Carl Ulrich, Archie Ritchie,
William S. Brown.

THE BRANCH DRAWING SCHOOL.—The season of 1906 and 1907 closes with the Branch Drawing School having an attendance larger than any season in its history, and we are now limited by the size of our school room, 17th and Venango Streets, being unable to meet the demand made upon us for instruction.

The intelligence of the students attending has been higher than any time in the past, and they have manifested an unusual interest in their work.

The grade of the work accomplished is all that can be expected, a high standard of understanding of the principles of mechanical drawing, neatness and speed being attained. The eagerness of the students to thoroughly learn their trade, coupled with the encouragement of the employers who have sent their young men to the school, has been an incentive to

persevering energetic work by the instructors, with a result that is particularly pleasing to the management.

Thanks are especially due to the Midvale Steel Co. and the Geo. V. Cresson Co., for their coöperation in the maintenance of the school. With a continuance of this coöperation we hope to improve still further in the work we have undertaken.

In conclusion I wish to say to the graduating scholars that I wish them all success in their undertakings, and that they will find the instruction they have secured at the Franklin Institute Branch Drawing School of Tioga a great benefit, which will re-pay them many times for their labors in obtaining it.

H. Roy Stacks,
Director.

The Following Students, Having Completed the Full Course of Four Terms, are Awarded Certificates:

Harry Billger,	Martin J. Burns,	Albert Grant,
Percy Gee,	Ross M. Kurtz,	Eugene Lyons,
Weston Mattis,	Edward Merriam,	Harry Oberheidt,
Frank Uhl,	Edward J. Danks,	Charles Deal,
Truman Hayhurst,	Harry Huber,	Harry Pennepacker.
Benjamin Stevens,		

The School of Mechanical Design.—The attendance in the several classes has been practically the same as last year. Our graduating class has been reduced in number, owing to the illness of some members, while others left the city and could not finish the course.

The usual ground has been covered in Mathematics and Strength of Materials. In connection with the work in Machine Design the students have designed and drawn a five-ton pillar crane, which was done in a very satisfactory manner, considering that all the drawing was done at home after working hours.

At the invitation of Dr. Stine, in charge of the Engineering Department of Swarthmore College, we spent one afternoon in the testing laboratories of Swarthmore College, and showed in a practical way how to find some of the values used in strength of materials. Of course, in the length of time at our disposal, we could only touch on this phase of the work. If the Franklin Institute could invest a small amount of money in laboratory equipment for the Engineering School it would aid us very materially in our work.

It is gratifying to notice that a number of graduates from the Manual Training Schools of the city, and from Girard College enter the classes in Mechanics and Strength of Materials, having had the required mathematics. We believe that if we had some systematic method of calling the attention of such students to the work done here it would result in a large increase in attendance and the general usefulness of the school.

We propose to make a few changes in the work of the school next year, in order that the course may be a little more practical than it is at present. The course in Kinematics will be given as a series of lectures, having a

standard book on the subject as reference, and our text-book on Machine Design will be changed to one more suitable to the course given.

L. M. ARKLEY, *Director.*

The following students have deserved honorable mention:

In Machine Design and Kinematics of Machines.

St. Phalle, F. de, Aroson, S. G.

In Strength of Materials.

Laherrere, Louis, Stokes, Percy,
Hatfield, Aloise, Forstrand, A.

In Trigonometry.

Davis, W. A. Gardiner, E. C.,
Donahue, R.

In Geometry.

Davis, W. A., Petri, A. H,
Donahue, R., Fennel, J. T.

In Algebra.

McDade, A. H., Greiner, H. L.,
Baumgartner, W., Paris, W E.

The following students have successfully passed their examinations, their names being arranged in order of merit:

Machine Design and Kinematics of Machines.

1 St. Phalle, F. de, 2 Aroson, S. G.,
3 Ruch, H. J.

Mechanics.

1 Laherrere, L.,
2 Hatfield, A,
3 Stokes, P.,
4 Sank, J.,
5 Moon, Wm.,
Equal. 6 Wackenhut, J. E., 7 Forstrand, A., 8 Champion, W. B., 9 Ferguson, G. H., 10 Schopp, W. J.

Strength of Materials.

1 Laherrere, R., } Equal.
2 Hatfield, A. }
3 Forstrand, R., } Equal.
4 Stokes, P., }
5 Sank, J.,
6 Schopp, W. J.,
7 Wackenhut, J. E.,
8 Champion, Wm. B.,
(9) Ferguson, G. H.

Trigonometry.

(1) Davis, W. A.,
2 Gardner, E. C., } Equal.
3 Donahue, R., }
(7) Fennel, J. T.
Equal. 4 Dougherty, S., 5 Petri, A. H., 6 Henszey, C.,
(8) Morrison, T.

Geometry.

(1) Davis, W. A.
(2) Donahue, R.,
(3) Petri, A. H.,
4 Fennel, J. T.,
5 Gardiner, E. C.,
6 Henszey, C.,
7 Dougherty, S.,
8 Morrison, T.

Algebra.

(1) Baumgartner, W., }
(2) McDade, A. H., } Equal.
(3) Greiner, H. L., }
(6) Pladder, E. C.,
(7) Pohrt, H.,
(8) Bowen, J. M.,

(4) Paris, W. E.,
(5) Senior, J. H.,
(9) Mauthe, J. J.,
(10) Kaupp, H. A.,
(11) Cornell, E. E.,
(12) Casey, V.,
(13) Cheesman, L.,
(14) Walther, A. W.
} Took Examination for Spring term only.

REPORT OF THE NIGHT SCHOOL OF NAVAL ARCHITECTURE.—The Night School of Naval Architecture met with a fair degree of success this year. On account of the present very unsatisfactory condition of the shipbuilding industry in this country, it was not expected that a very large class would be formed at the opening of the Fall term. But eleven students were enrolled; which, considering the very limited field from which recruits are obtained, was very encouraging.

Some difficulty was at first encountered in arranging a course suitable to the diversity of mental training with which the students came equipped. But careful attention to individual needs obviated this difficulty to a considerable extent; at least so much so as to enable the students to proceed together in classes, without sacrificing the advancement of the brighter pupils to the slower progress of those less proficient. It has always been manifest that the majority of the students in this course attend for the purpose of becoming better informed concerning some particular phase of the subject; therefore an attempt has been made to gratify this desire as much as possible, and it is believed that the results have been more beneficial than if an inflexible course of study had been adhered to, which of necessity subordinates individual need to the interests of the class.

The students have been considerably hampered by a lack of suitable textbooks. This has especially been the case in considering Practical Shipbuilding. The methods of procedure described in most books on the subject differ entirely from American practice, and the information is therefore of little value to those intending to pursue their profession in this country. However, the director has endeavored to supply this deficiency by means of informal lectures and addresses.

The attendance throughout the year has been exceptionally good; and the earnest attention and honest endeavor to learn, which all the students without exception have manifested, appear to justify the efforts of the Institute to continue this course.

Mr. Frederic J. Howard has satisfactorily completed the full two years' course, and is therefore entitled to a certificate.

M. H. KEIL, *Director.*

Erratum.

(*Journal, April, 1907, p. 258.*)

ART: FRAZER—SCIENTIFIC METHODS IN THE STUDY OF HANDWRITING. Line 16. For "blue ray absorbs the red and yellow" read "red constituent absorbs the blue and yellow rays."